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Vol. 3. No. 3 Pittsburgh, Pa. March, 1930

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WILLIAM LEE HOLLADAY

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Measurements—Industrial and Scientific
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◆

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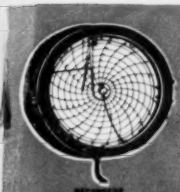

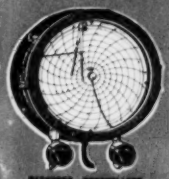

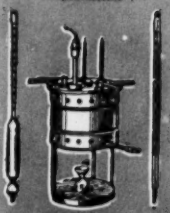

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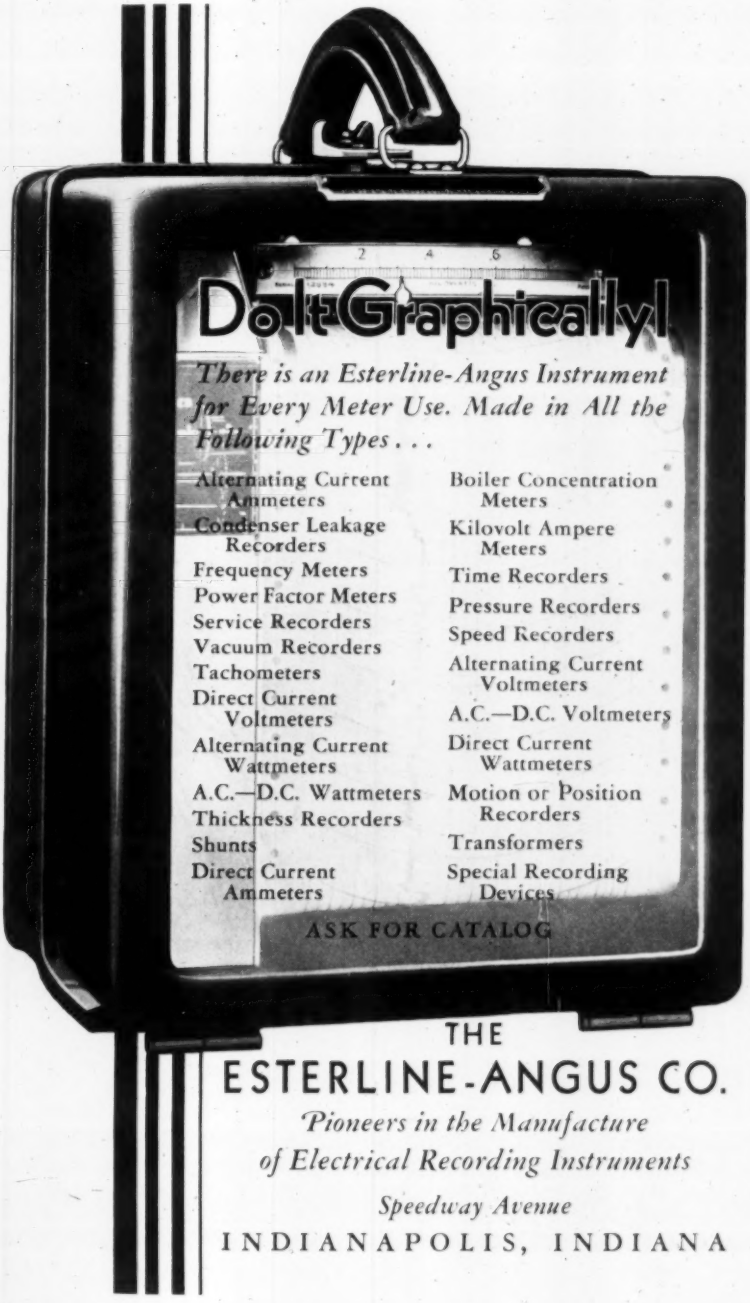

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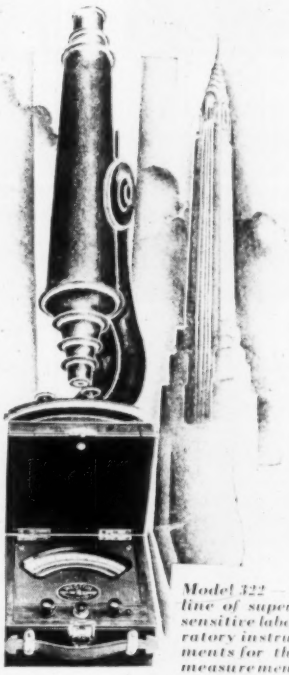

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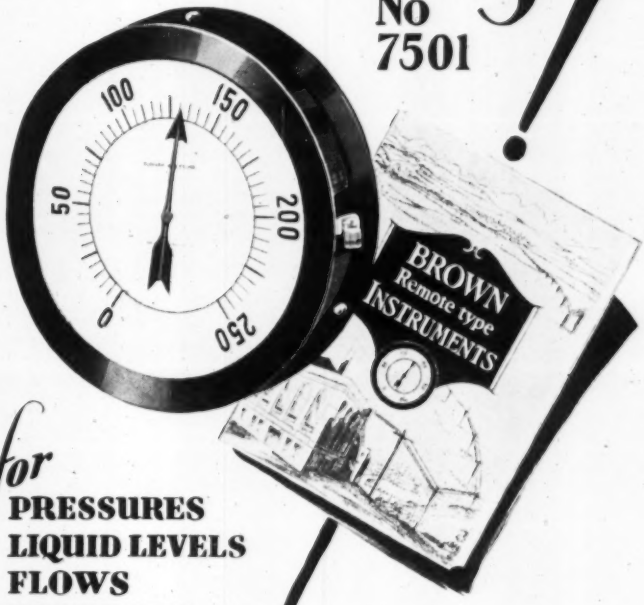

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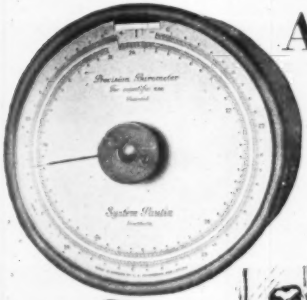

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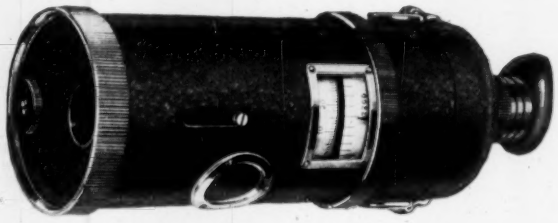

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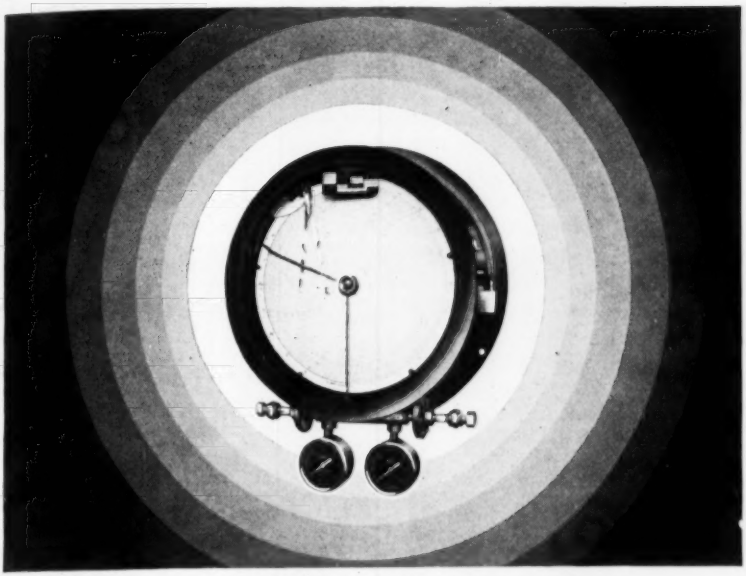

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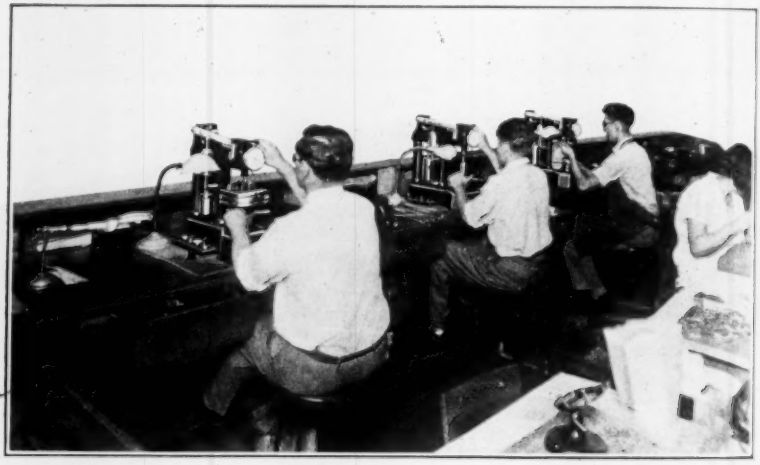

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INDUSTRIAL — SCIENTIFIC

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Vol. 3, No. 3 MARCH, 1930 Pittsburgh, Pa.

To Our Readers

RAPID progress is being made in the industrial applications of instruments. American industries, without exception, are applying instruments for increasingly important jobs. The future holds promise for yet greater developments. With engineers and production men awake to the possibilities of putting to work properly selected and correctly applied instruments, with thousands of such men looking for exact information on what to get and how to use it, it is evident that there is a very great need for a complete, reliable carefully compiled engineer's handbook of industrial instruments.

This need is nothing short of imperative, as America each year produces more engineers than the rest of the world. The need was recognized by many, but the task was so difficult that, as Mark Twain said about the weather, nobody did anything about it.

Our Engineering Editor M. F. Béhar has possibly done more to disseminate information on instruments and measurements than any one other man. Three years ago he organized an informal committee of instrument company advertising men to co-operate on educational efforts. He was author by invitation of the article "Regulation, Automatic" in the 14th Edition of Encyclopedia Britannica and collaborator on several other articles pertaining to industrial instruments. Further, he contributed the section on "Industrial Instruments and Their Uses" in the forthcoming revised edition of Rogers' "Manual of Industrial Chemistry."

In the January issue, the first installment of the series of articles under the caption "Engineer's Handbook of Industrial Instruments," by Mr. Béhar, appeared. The January and February installments were of a prefatory and general nature. In this issue a start is made on temperature instruments. A glance suffices to show that the subject is covered as engineers want it to be. If after reading these installments, they will write us their comments this will be appreciated by the editor, for it is our intention to give the instrument users what they need and what they want. Mr. Béhar has more than a thousand pages of manuscript. It must be adapted for publication. Such adaption will continue to depend, largely on constructive criticisms. Send them in!

[INSTRUMENTS Book-of-the-Month]

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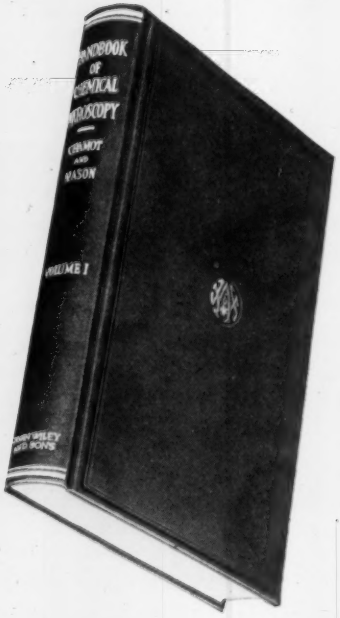

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Electric Refrigerator Measurements

*William Lee Holladay**

THE job of working with the owners of any type of mechanical equipment frequently calls for interesting measurements as well as those overworked twin brothers, tact and diplomacy. These measurements must not only be taken with a fair degree of accuracy but in such fashion and with such instruments that the customer will trust the results.

Our organization sells electric refrigerators. Starting when the product was first announced, its rapid acceptance has frequently made unexpected demands upon us, and several times has resulted in the planning of new instruments and methods.

The customer is generally interested in one of two things: temperature or cost of operation. Practically every complaint or request has its foundation in the inability, real or fancied, to get the right temperature at the expected cost. A small recording thermometer with a 72-hour, four inch chart, and a reverse scale temperature range of 30° to 70°F. is now in standard use among refrigeration people, is quite low priced, and will take care of almost any demand on the part of the household customer. Fig. 1 shows a sample chart, indicating every meal the family has eaten, every door opening, every change in temperature adjustment. If the cabinet is not crowded with food so that air circulation is unduly slowed down, it will indicate by slight temperature variations the starting and stopping of the icing unit. On a heavily loaded commercial job, a clever chart reader can also determine by the shape of the curve whether or not the cabinet is adequately refrigerated.

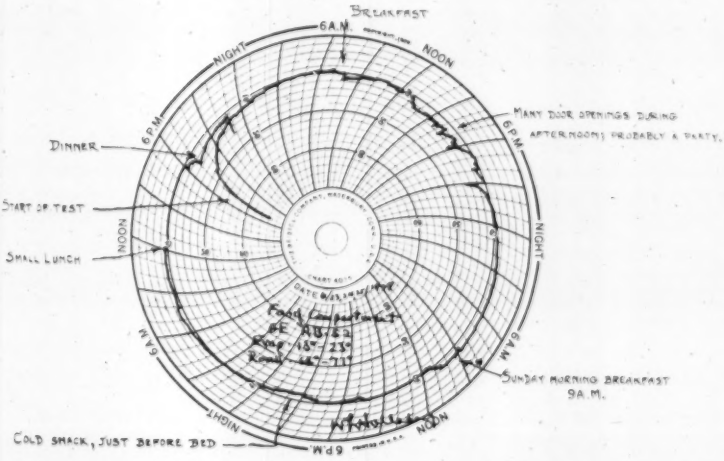

Fig. 1

However, the recording thermometer is for the hard-to-satisfy customer. For most jobs, an amply adequate test of temperature adjustment can be taken in a few minutes with a pocket thermometer, reading from 0° to 120°F[1]. A number of instrument people manufacture such a thermometer, either mercury or eosin type. Each refrigerator manufacturer has his own in-

*Product Manager, George Belsey Company, Southern California distributors of General Electric Refrigerators.

[1]Since refrigeration temperatures rarely go below 0°, the use of the Fahrenheit scale means all figures will be positive.

structions about temperature setting; almost never do they agree with actual field practice. We usually take thermometer readings in the chilling unit or evaporator, and set the automatic control to turn off the motor at a predetermined point: for average use, 12°. This gives a mean evaporator temperature of 18° and a cabinet temperature of 40°, quite adequate for food preservation. Box temperature almost never can be accurately taken with a standard registering thermometer, since door opening materially disturbs the readings. A minimum registering thermometer, left in for half an hour or more, will usually read within a degree of actual cabinet temperature but will of course be high. A better method, when possible, is to take the temperature of a bottle of water which has been in the cabinet for some hours. This will be unaffected by door opening and will truly represent food temperature.

Water cooler work, special jobs, ice cream cabinets and commercial work in general require a distance type recording thermometer, with a greater temperature range than the instrument first described. One having a ten-inch, reversed scale chart (standard for refrigerator work, having the low temperature on the outer circumference), range −20° to −70°F. will handle almost any problem. Equipped with a five-foot flexible tube, and a bulb of small diameter, it can be used for evaporator readings to show running cycle, or the tubing can be wrapped around the carrying case and the thermometer used self-contained. The instrument should by all means be of the vapor tension type, using sulphur dioxide or methyl chloride, since this type does not need to be compensated for room temperature differences.

No question, of course, is so close to a customer's heart as cost of operation. In our territory, served by several groups of utilities with conflicting rate schedules, and employing a large and constantly changing group of salesmen, we have found it almost impossible to make sure that the prospect for an electric refrigerator always hears the right story on operation cost. Complaints that the salesman said it could be run for a dollar a month, while the apparent cost was really much higher, have been handled easily and satisfactorily by the use of watt-hour meters, similar to regular house meters except that the right-hand dial reads in tenths of a kilowatt-hour instead of integral kilowatt-hours. Since a refrigerator usually takes about 1.5 kwh. per day, a two-day test gives results accurate to one kwh. per month. It is important to know before taking a test that the temperature setting is normal—a few degrees colder than recommended will run up the bill between one and two kwh. per month for each degree. One of the meters is pictured in Fig. 2.

The curve, Fig. 3, is plotted between official Weather Bureau mean monthly temperatures (averaged for 52 years) and monthly averages of about 200 meter tests on household installations. Southern California houses usually are not furnace-heated, so the kitchens and back porches where refrigerators are installed generally follow actual air temperatures rather closely. The curve is an approximate straight line, having, for all practical purposes, the equation,

Kwh. per month = Temp.°F.—15

Fig. 2

Sometimes complaints are received which read, in effect, "The machine runs all the time." Although there are recording devices on the market

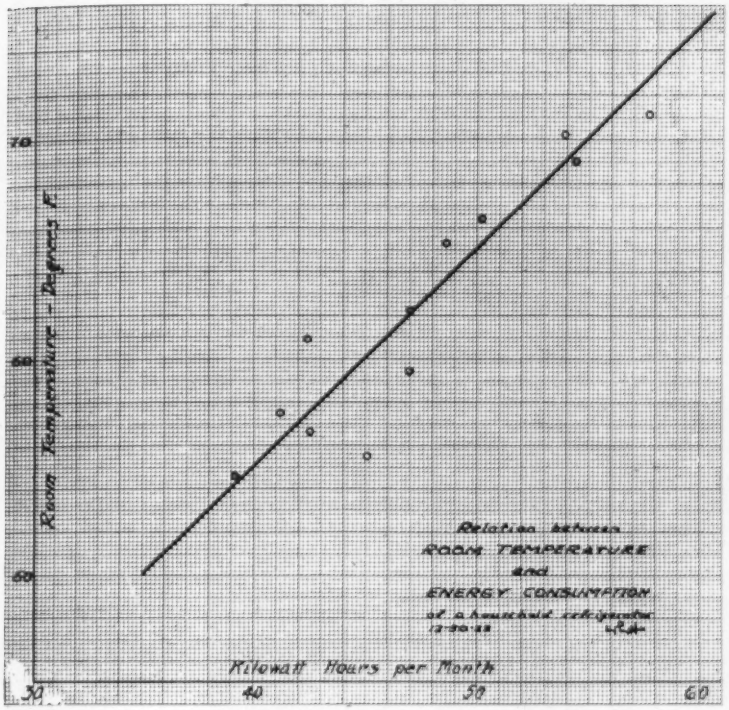

Fig. 3

which register the actual on and off periods, they are relatively expensive, and we have found that our old friend the watt-hour meter again can be of service. The number of watt-hours per day divided by the power consumption will give of course, the running time in hours per day, and the percent running time by dividing this figure by 24. Needless to say, we almost always find that the machines don't run all the time, or even within 50% of it.

The power consumption of any refrigerating machine is usually known by the field man making the test, but it can be obtained simply enough by the watt-hour meter and a watch having a second hand. First of all, count the number of seconds for 10 revolutions of the watt-hour meter disc. On the disc will be found a figure which multiplied by the number of revolutions per hour, will give watts. The arithmetic is fairly simple; suppose,

S = number of seconds for 10 revolutions,
K = disc constant
R = number of revolutions per hour, and
W = power in watts, then

$$W = KR$$
$$= K \times 3600 \times R \text{ per second}$$
$$= 3600\ K\ \frac{10}{S}$$
$$= \frac{36000\ K}{S}$$

The small 5-ampere 110-volt 2-wire General Electric I-16 meters have a disc constant of .6, and for this meter the formula reduces to $W = \frac{21600}{S}$.

Suppose the meter test shows that the customer's original complaint is apparently justified: the kilowatt-hour consumption is greatly above normal, while the wattage of the machine seems normal. There are 2 possibilities: either the machine is being overworked by excessive food cooling, door opening, ice freezing, high room temperature; or the machine is low in refrigerating capacity. The answer may be found by running the machine continuously for 24 hours in a room where the temperature is kept as nearly constant as possible, or where frequent temperature readings will give a good average figure. The final temperature inside the cabinet in which the machine is placed is controlled then by: (a) the heat leakage of the cabinet, (b) the room temperature, and (c) the refrigerating capacity of the machine. Knowing the cabinet leakage, a simple curve[2] can be drawn showing the relation between cabinet and room temperatures. Any units holding temperatures below the line are better than normal; those holding higher temperatures are rejected.

Interesting problems, these customers and their refrigerators.

[2]For obvious reasons, the actual curve is not shown.

GAS MEASUREMENT COURSE OPENS APRIL 15, 16 and 17

Seventh annual Southwestern Gas Measurement short course, which is conducted by the University of Oklahoma's College of Engineering, the Oklahoma Corporation Commission and the Oklahoma Utilities Association, will be held here April 15, 16 and 17. Representatives of natural gas utilities, natural gasoline manufacturers and meter manufacturing companies will attend.

The Roller-Smith Company makes the following announcements:

M. W. Seymour is now associated with the New York office as a Sales Engineer. Mr. Seymour is a graduate of Brown University and for several months prior to his connection with the New York office he was located at the Company's Works in Bethlehem, Penna.

H. D. Stier, 101 Marietta St., Atlanta, Ga. now represents the Roller-Smith Company in the States of Alabama, Florida, Georgia, North Carolina and South Carolina.

H. N. Muller Company, First National Bank Bldg., Pittsburgh, Penna. now represents the Roller-Smith Company in Western Pennsylvania, West Virginia and the Youngstown District in Ohio. Associated with H. N. Muller are H. E. Ransford and F. E. Harper.

An Early Use Of Magnetism For Mechanical Testing

*Dr. S. R. Williams**

IN giving a résumé[1] of what has been done in studying the mechanical properties of a body by means of its magnetic characteristics, it is of interest to note that as far back as 1867 Saxby[2] proposed to "test the iron of guns by magnetic power."

The method of Saxby appears to be a very simple one if the description given by Paget is correct. If a bar of soft, homogeneous iron is laid in a position normal to the earth's magnetic field it will become feebly magnetized normal to the axis of the rod. When a sensitive "magnetic needle is slowly passed in front" of such a bar, "the needle will not be disturbed from its proper direction." This is shown in Fig. 1.

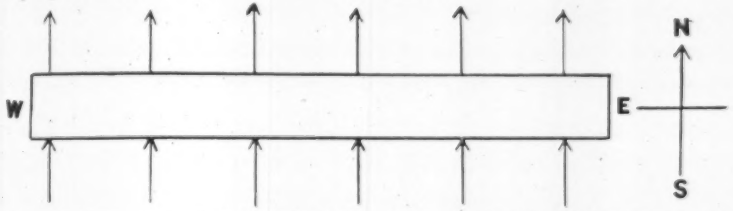

Fig. 1. A homogeneous iron rod, when placed in an East-West position normal to the earth's field, is feebly magnetized normal to its axis. A sensitive compass needle remains normal to the axis of the rod.

"All this refers to regularly homogeneous bars of best quality—to bars without any mechanical solutions of continuity. With internal flaws or interruptions of continuity the bar is no longer regularly magnetic. It has long been known that a good compass needle, or a good permanent magnet, must be homogenous and without flaws in order to take and retain its maximum amount of magnetism. In a word, *any mechanical solution of continuity is accompanied with a polar solution of continuity*, and the given bar or mass with flaws—whether permanently magnetized or temporarily so by the inductive action of the earth—is no longer one regular magnet, but several different magnets, with the different magnetisms separated from each other. The delicately-poised magnet of a compass can thus be made

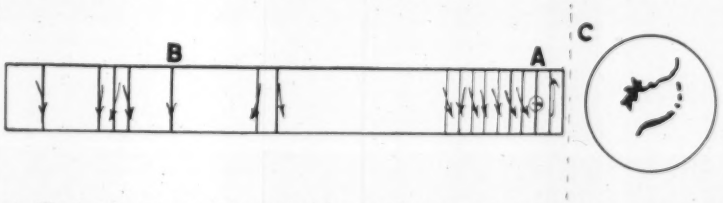

Fig. 2. This shows an iron rod which is not homogeneous. The compass needle does not remain normal to the axis of the rod as it moves along the rod. The point C indicates a complete reversal of magnetization.

to tell the presence of such solutions of continuity." Fig. 2 "will illustrate the manner in which the compass magnet is affected by the presence of cracks, of solutions of continuity, in the bar, which is supposed to be lying in the equatorial magnetic plane, or east and west. The magnet was tra-

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[1] Williams, INSTRUMENTS, Jan. 1928, pages 29–38.
Spooner, INSTRUMENTS, Jan. 1929, pages 5–12; Feb. 1929, pages 57–63.

[2] Paget, The Engineer, Nov. 29, 1867, page 463.

versed in a parallel line with the center of the bar. As long as the iron was perfectly sound the needle stood at right angles, in proper position, in fact without being disturbed. Such a position is shown it B. Slight deviations had previously been caused, getting repeated towards the middle of the bar, as indicated by the two small arrows there. On traversing the needle towards the end—and a quick to-and-fro motion is of great use near a suspected spot—it got gradually deviated at A, until it entirely reversed at C, indicating the presence of the flaw, shown in the full size cross-section, after cutting the originally longer bar at that spot."

Saxby tested his bars with different sized compass needles. In general the results were the same. The bars were reversed end for end in the magnetic equatorial plane and the same faults were again located at the same points on the bar. While the results were not so good Saxby found that he could detect flaws in the rods even when the rods were placed parallel to the earth's magnetic field.

The smiths of the English royal dockyards had Mr. Saxby demonstrate his methods in their presence. They fixed up several samples for him and it would appear from Paget's description of the tests that Saxby was able to find the flaws in every case. "As examples out of many, in the center of a bar, (Fig. 3), of 1 inch square forged iron, was welded a piece of unmagne-

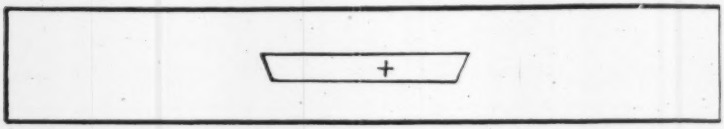


Fig. 3. A bar of steel about 5 inches long was welded into a square forged piece of iron. This piece of steel was picked out very easily by Saxby's method.

tized steel about five inches long. The needle detected a fault at about the center of the piece of steel."

Not only were artificial discontinuities picked up by Saxby's method but also chance flaws in the materials were detected. A long series of experiments is described by Paget in reviewing the tests made by Saxby. One other test may be cited: "In a piece of 1-inch gaspipe had been inserted unknown to Mr. Saxby, an iron plug at each end, as shown in Fig. 4. The magnet soon detected the central break in the continuity of the iron mass

Fig. 4. Iron plugs were inserted into a piece of gaspipe. The discontinuity of the plugs at A were very readily picked up by Saxby's method.

as shown by the position of Mr. Saxby's mark at A."

Saxby also appears to have been successful in determining whether a weld was a good one or not. On the whole Paget makes Saxby's method of testing iron by magnetism to be a very simple and effective one. In a sense Saxby's method is a fore-runner of some of the methods now being used. In closing his account of Saxby's work, Paget makes the following statement, which may characterize all magnetic testing, viz.,

"There is little doubt that the magnetic method is a test of the homogeneous character of the iron and of its freedom from fissures and cracks, and so far it undoubtedly forms a test of quality."

The Engineer's Handbook of Industrial Instruments

M. F. Béhar*

PART I—GENERAL

Industrial Service Conditions

Temperature is by far the most important, not only of processing conditions but of working conditons and even of storage conditions. While its successful industrial measurement is comparatively recent, its attempted control for the sake of bodily comfort goes back to prehistoric ages, and intelligent observations of its effects as a processing condition were made and handed down by ancient cooks and bakers, spinners and weavers, smelters and smiths, potters and ceramists, and other fore-runners of industrial engineers, long before a distinction between heat and temperature was even suspected. Every industry is a temperature industry and every process is a temperature process . . . Exceptions? Let us see: take the mining industry and in particular the magnetic separation process, as an extreme example. No exception there: For when a separating plant is erected in the Far North, something has to be done about temperature as a working—if not a processing—condition. The general rule still stands. The only thing suggested by the separating process example is that in that particular case the "one best" temperature is anywhere in the comfort range. In that sense our example furnishes an exception, for the optimum temperature of most industrial processes lies within a narrow range—a few degrees too hot or too cold and production is spoiled. If it were not so you would not be reading this book.

It must be emphasized at the outset that industrial service conditions compel a re-definition of the laboratory meaning of "results." Many a laboratory worker nurses and coddles his instruments, and in effect creates special conditions under which his pets can "do their stuff" to the fourth decimal. Some hard-boiled production men may take the opposite extreme and demand the impossible. The engineer, equipped with knowledge of the principles related to the "application" and to the instrument, takes a happy medium—which it is a purpose of this book to promote. Temperature gradients in many pieces of industrial equipment make it utterly hopeless to expect to measure "the temperature." In most furnaces, ovens, kettles, pipes and boilers the walls are cooler than the enclosed space except where heat is applied; in refrigerated apparatus they are generally warmer. In large drying compartments the gradient often exceeds 50°F when the desired temperature is only around 200°F, especially when trays or other obstructions prevent good circulation. The measurement of the temperature of non-incandescent pieces of solid materials inside an oven or other apparatus is also a difficult job. Even in the case of an enclosed space—empty but for air or gas—in which the temperature is uniform (except for a thin layer next to the walls) and in which the thermometer bulb or thermocouple junction is located at the exact center, the readings will ordinarily be affected by conduction along, and by radiation from or to, the bulb chamber, well or socket. When the air or gas is in motion, as in a flue or

*Engineering Editor

duct, there is no such thing as "the" temperature and what is required for exact and complete knowledge is not a measurement but an investigation—to which statement power plant engineers* will say amen! But aren't flue gas thermometers in constant use everywhere? Certainly; and their successful use provides an illustration of the engineer's "happy medium" view of temperature measurement and control:

1. Painstaking scientific methods and the use of delicate non-commercial temperature instruments are unnecessary for the successful routine conduct of commercial processes in industrial plants.

2. Measurements of "the temperature" need not be "true" but they can be dependable or significant if good instruments are properly installed, with special care that their bulbs or couples be placed where the temperature is representative. Actual "immersion" is not necessary: for open-hearth work the inner face of the *roof* is all-important; in glass melting the couples go in the *walls* at a distance from the inner face; with radiation and optical pyrometers it is a question of proper *aim*; and always, everywhere, it is a matter of *judgment*.

3. Automatic temperature control can be realized if the primary or sensitive element be sufficiently responsive to temperature variations, the other elements adequate for their respective functions, and the whole properly installed on equipment that lends itself to control.

After all, these statements are self-evident, for they imply that the process equipment (a 10,000 HP boiler or a candy kettle) must be suitable for the use of temperature instruments; and that the instrument must be reliable. The designers and makers of plant equipment, as was pointed out in Chapter I, now supply industry with apparatus that lends itself to temperature control. And as for the instruments makers—just one example: A regular model temperature controller (thermocouple primary element, millivoltmeter secondary element, gas-filled mercury-in-quartz relay) is guaranteed to respond to changes of temperature within one-tenth of one percent of its range—provided, of course that the controlled apparatus be suitable. The makers of thermometers, pyrometers and automatic systems seem to be several laps ahead. Industrial temperature instruments are really more accurate than is required by industrial service conditions.

Temperature Measurement

But before coming to these instruments it is necessary to take up—briefly and painlessly—that peculiar thing, temperature, which they measure and and control. This requires a little excursion into the realm of science—just deep enough for the curious but busy engineer. At the start come two frequent questions: First, What kind of a thing is temperature? Second, What is it?

Editor's Note: For the discussion of these two questions see the February installment of The Engineer's Handbook of Industrial Instruments, *Instruments*, pages 129-135.

Classification of Industrial Temperature Instruments

The first classification is according to function—into indicating, recording and controlling. Others are according to range, form, property of matter or other temperature effect utilized, etc. There is some unavoidable overlapping, no matter what method is used. First, a few definitions, as presented by the Industrial Group of the Association of Scientific Apparatus Makers, after discussion with the Bureau of Standards and other authorities:

*An excellent discussion of the precautions to be taken in measuring temperatures is given in the A. S. M. E. Power Test Codes, Instruments and Apparatus, Part 3-Temperature Measurement, Chapter 1—General.

1. *Thermometer*: A device for measuring temperatures.

2. *Pyrometer*: A device for measuring high temperatures. The term is applied to those devices, the principal use of which is for measuring temperatures above a red heat (about 500°C or 932°F).

3. *Resistance Thermometer*: A thermometer which indicates temperature by means of the change with temperature of electrical resistance of one of its parts. It is a pyrometer when used at high temperatures (above 500°C [932°F.]), and in such case is preferably called resistance pyrometer.

4. *Radiation Pyrometer*: A pyrometer which indicates temperature by means of the change with temperature of the heat radiated by a hot body. As nearly as possible the total heat radiated is used. Usually this temperature is measured by a thermocouple.

5. *Optical Pyrometer*: A pyrometer which indicates temperature by means of the change with temperature of the light emitted by a hot body. As nearly as possible light of a single color (wave length) is ordinarily used.

6. *Thermocouple*: A pair of electrical conductors so joined as to produce a thermal e. m. f. when the junctions are at different temperatures. It consists of conductors of different material permanently joined at one end, the other ends being free to connect to an instrument for measuring e. m. f.

7. *Thermoelectric Pyrometer*: A pyrometer which indicates temperature by means of the change with temperature of the e. m. f. of a thermocouple. It ordinarily consists of a thermocouple, a millivoltmeter (or other means of measuring e. m. f.) and connecting leads. The measuring instruments may be classified as follows: Millivoltmeters; potentiometers; their combination of modifications.

A classification of *industrial* temperature measuring instruments is a necessity, for scientific classifications are of little use to plant men. The first industrial classifications were made independently by Richard Rimbach and by the writer and were published in INSTRUMENTS, Volume 1, Pages 441 and 467. The former is extremely valuable in that it gives the ranges of many substances used, such as mercury, pentane, xylene, ether, aniline, etc., but the main division is into "Distance" (restricted to radiation and optical pyrometers) and "Contact" (including the distant-reading connecting-tube and connecting-wire instruments). The latter was made up especially for use by production men. As revised to January 1, 1930, it follows:

TABLE I—INDUSTRIAL CLASSIFICATION

I—Indicating Thermometers

1. Liquid-in-Glass (Visible Column)
   - (a) Mercury (−38 to + 540°C.)
     - (1) Etched Stem ("Laboratory" or "Chemical")
     - (2) "Industrial"
     - (3) "Miscellaneous" (Pocket, wall, etc.)
   - (b) "Spirit" (Typical ranges: pentane −180 to +20°C, alcohol −70to +120°C).
     - (1) Etched Stem
     - (2) "Industrial"
     - (3) "Miscellaneous" (Pocket, wall, etc.)
   - (c) Gallium-in-quartz (+31 to +1000°C.)
2. Pressure Spring
   - (a) Mercury (−38 to +538°C)
     - (1) Non-compensated (Tube length 25 ft.)
     - (2) Head-compensated (Tube length 35 ft.)
     - (3) Fully-compensated (tube length 150 ft.)
   - (b) Non-mercurial Liquid Expansion (−40 to +400°C)
   - (c) Vapor Pressure (Range limits −30 and +370°C)
     - (1) Progressive Scale } (Tube length 150 ft.)
     - (2) Uniform Scale }
   - (d) Gas (−130 to +538°C. Tube length depends on bulb volume.)
3. Solid Expansion
   - (a) Bi-metallic (upper limit about 550°C)
   - (b) Metal and Refractory (upper limit for Monel about 650°C)
4. Electrical Resistance
   - (a) Nickel (−180 to +120°C)
   - (b) Platinum (−180 to +1000°C)

II—Indicating Pyrometers

1. Thermo-electrical (Industrial limit 1600°C)
   - (a) Galvanometric
   - (b) Potentiometric
   - (c) Semi-Potentiometric
2. Optical (only over 600°C)
3. Radiation (only over 500°C)
4. Fusion (supplementary)

This list purposely omits calorimetric thermometers and pyrometers, pneumatic pyrometers, mercury-vapor pyrometers and other devices which for plant service have been eclipsed by industrial instruments of greater accuracy, convenience and serviceability. The following discussions skip over certain items of the above list, go on beyond indicators, and are therefore differently numbered and lettered.

It is regretable that some authors or editors of standard reference works still cling to the division of "electrical thermometry" into "1, the thermopile" and "2, the resistance thermometer." The 1929 edition of what is perhaps the most famous of all reference works does just this, with the result that the treatment is confusing to practical men. The scientific fact that temperatures below the ice point *can* be measured by means of thermocouples is of little consequence. *Thermometry and pyrometry are different in practice.* Pyrometers are made for "high" temperatures beyond the practical limits of all instruments commonly known as thermometers, and hundreds of keen minds concentrate on their development for the measurement and control of such "high" temperatures.

Similar practical considerations emphasize the necessary practical distinction between thermoelectric pyrometers and radiation pyrometers in which a tiny thermocouple is employed. A thermoelectric pyrometer, as every engineer knows, is one with a "fire end" that "you stick into the furnace."

Equally misleading—and untrue for that matter—are the statements that continue to be made in new manuals and reference works to the effect that the International primary standards are the "verre dur" thermometer and the nitrogen thermometer. Such statements can only be attributed to the persistence of the idea that the thermodynamic scale of absolute temperature can only be realized in such instruments. The plain fact is that these instruments are *obsolete* as primary standards for temperatures all the way from the oxygen point to the highest measurable temperatures. The engineer can confidently use resistance thermometers and thermoelectric and optical pyrometers which he has ordered from a catalogue and be happy in the knowledge that he is handling instruments exactly similar in principle (and the latter almost in construction) to those selected as primary standards by the International Conference.

Thermoelectric pyrometers may be used for low temperatures as in refrigeration work, but they seldom are. They may also be used for "water ranges" of temperature, but such applications are also unusual. Only a few special problems in the measurement of temperatures below 900°F call for the use of pyrometers in preference to thermometers. Among these applications are measuring the temperature of a fast-moving surface, of a very small sunken surface, such as that of a mold or die, etc. Innumerable other applications are possible by the use of portable self-contained thermoelectric pyrometers and if such portable immersion pyrometers were made for thermometric ranges, the practical distinction between pyrometers and thermometers would almost vanish. The very fact that such immersion pyrometers are *not* being manufactured and sold for "low," "room," "water" and "medium" ranges proves that in practice thermoelectric pyrometry is not a branch of electric thermometry and that there is a real distinction between pyrometers and thermometers.

Ranges—There is a rough and informal classification of instruments within each class and type, which cannot yet be laid down in an exact way. In fact it has never been put in writing, but it is understood in the speech of the instrument-making and instrument-selling fraternities. Certain expressions often heard in conversations are so illuminating that they deserve to be recorded here, so that some may be learned by users of industrial temperature instruments. For example the expression "superheated steam thermometer" immediately connotes one scaled above the "water range" (scale 30 to 240°F) and with a good pressure tight connection. Other ranges, the names of which are illuminating, are, for thermometers, "low," "brine" or "refrigeration," "room," "hot water," "outside" or "atmosphere" or "weather," "canning," "oil still," "dryer," "milk" (including several) "enameling," "boiling" "feed water" (and other power plant specials), etc.

For pyrometers, "brass," "iron," "combustion," "furnace" (oil, gas, electric, etc.) "cement" "ceramic," "glass" and other names of ranges.

All of these terms bring vivid pictures to mind. They deserve to be popularized now, so that they may be thoroughly standardized soon. Long dry lists of ranges in thermometer catalogues could really be made interesting if they were supplemented by a parallel column of such attractive terms. It would pay, for it will help users to specify correctly.

PART II—INDICATING THERMOMETERS

a. Etched Stem Thermometers

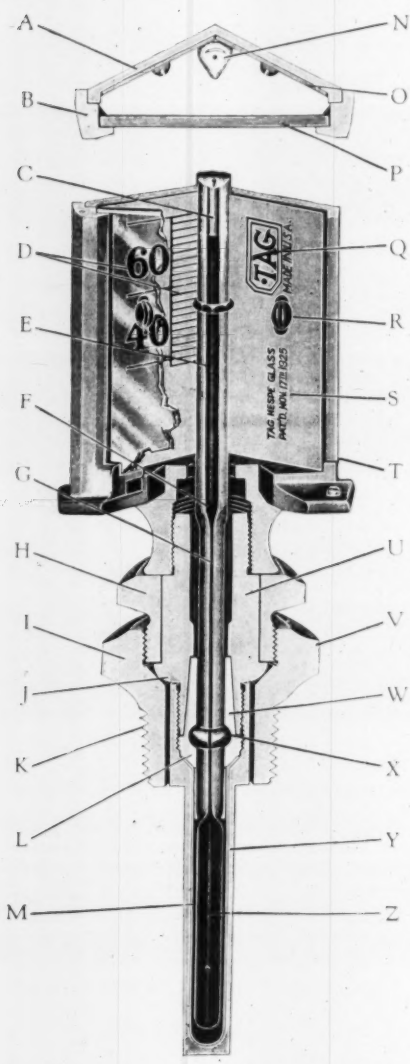
These instruments, also known as engraved stem or laboratory or chemical thermometers, while indispensable in the laboratory, cannot be discussed at length here, for their fragility makes them unsuitable for industrial plant service. Provided with closely-fitting or loose cylindrical metal cases they are known as armored or pocket thermometers and are of great importance in testing, but testing instruments are by virtue of their definition *not* "industrial" instruments, and hence they do not come within the scope of this book. The sensitivity of these thermometers greatly exceeds that of the industrial types and the lag is less, but this is due in part to the greater thinness of the bulbs. The higher grades are instruments of precision. Nevertheless, their use is mostly confined to the laboratory and to occasional testing, such as the measurement of steam temperatures with the aid of mercury wells, in steam plant work.

Emergent stem corrections, methods of calibration and standardization, notes on mercury wells, and other useful data, will be found in the Appendix.

b. Industrial Thermometers

These widely and importantly used industrial instruments embody the usual glass tube thermometer, but it is completely surrounded and protected by metal and plate glass. The removable plate glass front, framed in aluminum, bronze, or other material, may appear to be a minor item, but it distinguishes those thermometers which really deserve the title of "industrial" from the "oval-back," "open-V" and other instruments, which—while they are called "industrial thermometers" by some makers, should rather be classified as "miscellaneous" or "semi-industrial type" thermometers. Out of more than 100 thermometer makers in the United States, not more than half a dozen or so manufacture veritable industrial thermometers. Recent years have witnessed a remarkable development in the mechanical construction of the industrial thermometer. Fig. 1 illustrates the details of modern construction of a representative make. In addition to superior mechanical construction, industrial thermometers embody hidden virtues that show up in actual service, and distinguish them further from the semi-industrial types. The glass itself meets exacting specifications and the raw tubes are selected with care (we recall seeing a big barrel of deliberately smashed "rejects" in one factory). It is thoroughly heat-treated ("annealed," "aged" or "seasoned") to minimize the inevitable deformation which glass *always* undergoes. Bulbs and capillaries are often made of special compositions of glass. A dry, inert gas (usually nitrogen) fills the bore above the mercury and prevents "thread-break" or "separation of column." Each pair of scales is graduated for its tube, which is "pointed" at several temperatures; and each tube so held that it cannot slip up or down between the scales.

Mercury of exceptional purity is almost always used as the liquid. Some old timers continue to specify red spirit, but one of the two advantages of colored alcohol—its visibility—is outweighed by its inferiority in almost every other respect, and in spite of all precautions by manufacturers the color continues to fade—sometimes with exasperating rapidity! The other



advantage is that it can be used for low temperatures, down to −90°F, but its upper limit is low: +150°F (about 400°F for other "spirits").

Principal Standard Forms of Industrial Thermometers—The industrial thermometer needs no advocate to defend it from the inroads of other temperature indicating instruments. It must be said, however, that a more widespread acquaintance with the standard forms of industrial thermometers would in many cases make it unnecessary to specify another indicating instrument when an industrial thermometer would do as well. It frequently happens that in a manufacturing department where a large number of, say, straight-form short-stem industrial thermometers are giving satisfactory service, the man in charge, forgetting that there are other forms, will order a dial thermometer or electrical resistance thermometer, thereby ending standardization. Fig. 2 shows some of the possibilities of industrial thermometers in this respect. Only a few standard forms are shown. There are many "specials" for various industries—different in appearance but of the modern "industrial" construction whenever that designation is used in the catalogue of a reputable maker.

Principal Standard Connections for Industrial Thermometers—1. *Fixed* (Fig. 3) This is the simplest style of connection for permanently attaching a thermo-

Fig. 1. Construction of a Typical "Industrial" type of Thermometer.

A—Scale case. B—Interchangeable front frame. C—Gas space above mercury. E—Mercury. F—At this point, the glass has the lens front—as may be seen by comparing the apparent width of the mercury. G—Cylindrical portion of glass tube, between scale case and bulb, with fine mercury bore to eliminate error due to variable immersions. (Important in long-stem portable thermometers.) H—Coupling nut, revolving freely on stem connecting piece. I—Union connection hub for attaching thermometer. J—Seat. K—U. S. Standard pipe thread. L—Lower portion of packing seals mercury conducting bath in bulb chamber. Air space between surface of conducting bath and packing allows for bath expansion at high temperatures. M—Mercury conducting bath allows rapid transmission of heat from outside of bulb chamber to the thermometer bulb. N—Magnifying lens front tubing. O—Scales. P—Plate glass front. R—Round-headed screws permit removal of scales for cleaning, one at a time and replacng in correct position. T—Ventilation openings at back prevent glass front from being obscured by condensation of moisture on inside of glass. U—Connecting piece. V—Hexagonal wrench head. W—Asbestos packing. Y—Bulb chamber. Z—Bulb. (*C. J. Taghabue Mfg. Co.*)

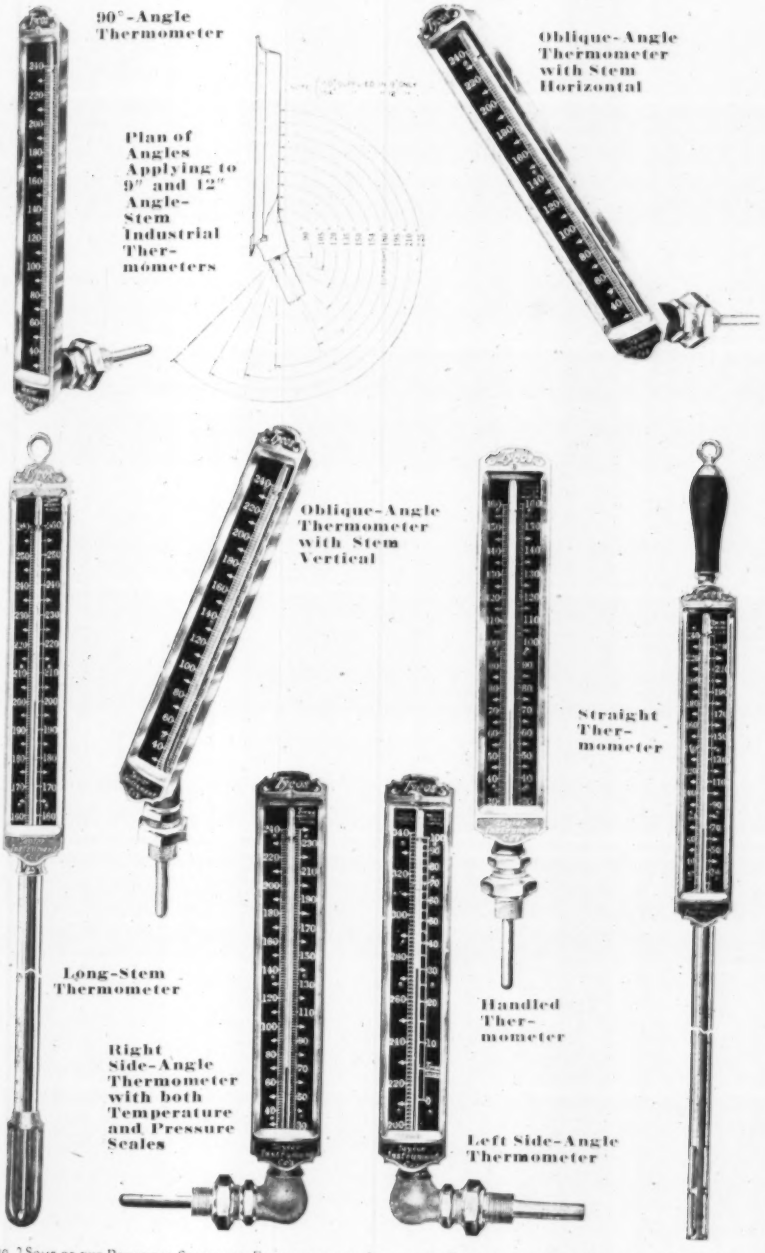

90°-Angle Thermometer
Plan of Angles Applying to 9" and 12" Angle-Stem Industrial Thermometers
Oblique-Angle Thermometer with Stem Horizontal
Oblique-Angle Thermometer with Stem Vertical
Straight Thermometer
Long-Stem Thermometer
Handled Thermometer
Right Side-Angle Thermometer with both Temperature and Pressure Scales
Left Side-Angle Thermometer

FIG. 2 SOME OF THE PRINCIPAL STANDARD FORMS IN WHICH INDUSTRIAL THERMOMETERS ARE REGULARLY MADE UP

Taylor Instrument Companies)

Fig. 3

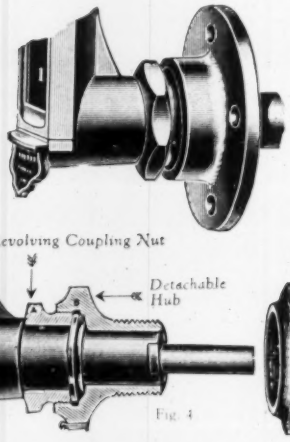


Fig. 4

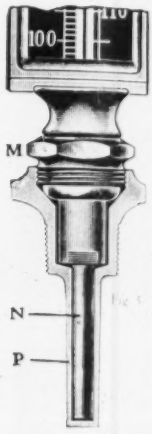


Fig. 5

meter to an apparatus, (a) Fixed Thread—The illustration shows a straight form thermometer with fixed Standard Pipe Thread connection. (b) Fixed Flange—Instead of the wrench head and pipe thread, a fixed flange may be furnished. (c) Pipe Threaded Flanges—When the wall of an apparatus is too thin to enable a thermometer to be securely attached by means of a threaded connection (or when it is necessary to provide a threaded opening at a slant) the thermometer is attached by means of its s. p. t. to a flange, which can be bolted, riveted or sweated to the apparatus. (d) Running Thread and Lock Nut—In this form of connection there is a square shoulder immediately below the wrench head; and the thread is U. S. Standard machine thread (not tapered).

2. *Union*—(Fig. 4) A union connection permits a thermometer to be securely attached without revolving the scale case, which can be faced any direction before tightening the connection. This is of special advantage in the case of angle thermometers. The essential feature is a revolving coupling nut, free to turn on the connecting piece. Its function is to hold the thermometer securely to the fitting (hub or flange) while sealing the opening through which passes the stem of the thermometer. The lower illustration of Fig. 4 shows how this is done. It illustrates a union hub, which has a standard pipe thread on the outside. For thin walled apparatus, a union connection flange as shown in upper illustration of Fig. 4, may be supplied instead of the hub.

3. *Separable Socket*—(Fig. 5) This connection has all of the advantages of the union connection; and one more, which is that the thermometer may be removed without creating an opening in the pipe or apparatus. It therefore is used where pressure or vacuum is a factor. Another advantage is that in the case of corrosive fluids, sockets may be made of special materials and even if they have to be renewed periodically, the expense is small compared with the cost of a good thermometer. A separable socket is really an additional chamber or well, which exactly fits over the bulb chamber and stem of the thermometer.

4. *Adjustable*—(Fig. 2, bottom) While handle top and straight form adjustable connection thermometers are all portable, it is often desirable to attach them to a kettle or other apparatus; even if only in order to locate

stem and sensitive bulb properly. Hence various clamping devices applied to the plain tubular stem.

For various standardized industrial processes special connections and fittings have been devised, including ventilated fittings for steam-jackets, wall fittings, etc. Thermometers of both the industrial and semi-industrial workmanship may be obtained with such fittings. Look for the designation.

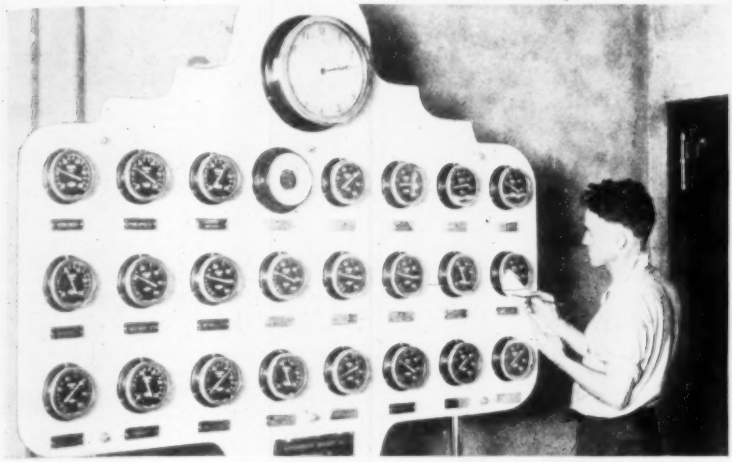


Fig. 6. Centralization of Temperature Indication. Pressure-Spring Thermometers with Their Dials Assembled, While Their Bulbs are Applied to Measure Room and Storage Temperatures, and Water, Heating and Refrigeration Lines. (*Foxboro Company.*)

Bare Bulbs—On many applications, particularly where gas temperatures must be measured, the glass bulb should not be enclosed in a bulb chamber because the thermal lag might be objectionably great. On such applications it is well to specify a bare bulb, protected by a suitable guard such as a perforated metal tube of comparatively large diameter. Flanged or s. p. t. union connections are optional. Lag is much less than with a bulb chamber, but a pressure-tight connection is ordinarily impracticable.

Principal Sizes of Industrial Thermometers—By "size" is meant the length of the pair of scales alongside the visible portion of the tube. The standard sizes are 7-inch, 9-inch, and 12-inch, which means that the scale cases are between an inch and a half and two inches longer.

Increasing the Readability—The visible portion of the tube of an industrial thermometer has an approximately triangular cross-section, with a rounded edge facing the observer, known as a "lens front," which magnifies the apparent width of the mercury thread and facilitates reading the instrument. In addition, the tube is often made with a strip of bright red glass behind the mercury bore, visible only above the top of the mercury column and affording a striking contrast, catching the eye at first glance.*

High Ranges—Manufacturers of industrial thermometers list them in their catalogues in ranges up to 1000°F (538°C). The bulb chamber construction and other details for ranges above 750°F (400°C) are special; there is an extra charge; lag is greater; unavoidable aging effects necessitate fairly

*There are many old and new varieties of red-back mercury-in-glass thermometers. After examining a presumably complete collection of these varieties the author would call attention to the relative worthlessness of the "ruby back" forms which came out about forty years ago, in which the red shows alongside of the mercury as well as above. This is not true of modern tubings such as those made under the Hespe patent, which are pleasantly "readable."

frequent calibration, and when the thermometer is continuously used above 900°F (482°C) the destructive effects may soon make the instrument unserviceable. On the whole, mercury thermometers of the typical "industrial" construction are not recommended for use above 900°F (482°C). Special instruments, variously known as tempering bath thermometers, type metal thermometers, flue gas thermometers, etc., when made with care of selected materials, may be exceptions to this statement.

Fig. 7 (at left) Mercury Actuated Pressure-spring Thermometer—Mechanism (Consolidated—Ashcroft Hancock Co.)

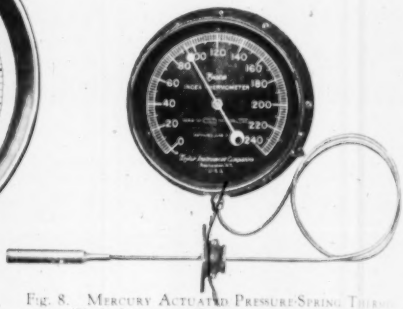


Fig. 8. Mercury Actuated Pressure-Spring Thermometer (Taylor Instrument Cos.)

c. Gallium-in-Quartz Thermometers

One wishes that one could report that the gallium-in-quartz thermometer has been promoted from the laboratory market to the plant market, but this has not officially happened and there is as yet no handy, simple visible column thermometer on the industrial market for measuring temperatures above 1000°F. The commercial gallium-in-quartz thermometer when it appears (before the next edition of this book, perhaps?) will probably give as reliable indications at 1700°F. as are given at 950°F. by mercury industrial thermometers with high-pressure nitrogen filling, special bulb glass, special capillary glass and special bulb-chamber construction to prevent erratic changes in bulb volume—essential features which make them rather costly.

Quartz is a common mineral of many forms and methods of occurence. In instruments it is used raw or natural only for pivot jewels. (Therefore "gallium-in-quartz" is technically incorrect). Fused quartz, quartz glass, and such quartz materials are importantly used in industrial temperature instruments, for resistance bulbs, thermocouples, mercury thermostat switches, fusion cones, etc. As a matter of fact, natural quartz becomes something else when heated: It inverts to tridymite with a 15% increase in volume at 870°C, and at 1470°C changes to the ordinary Mexican cristobalite. The gallium thermometer (for which the author predicts a great future when someone offers it to industry) will have to utilize not "quartz" but some industrial quartz product. As far as can be learned now, a material with a softening point of 1750°C has been produced by the General Electric Co. It would seem that the industrial gallium-in-quartz thermometers will be readily applicable for temperatures up to 1000°C (1770°F). The chief difficulty appears to be the resistance of quartz materials to etching. This precludes the early introduction of *laboratory* instruments with scales etched on the stem, but not of *industrial* instruments (with separate scales) the tubes of which are merely marked by small scratches when "pointed."

Gallium. The small amount of refined gallium at present (1930) available is a real obstacle—that is to say merely a challenge to American ingenuity. (So were aluminum and helium costly and "rare" not so long ago. It will be the same story with gallium!).

d. Pressure-Spring Thermometers

These instruments (Figs. 6-11) are usually known as dial thermometers or index thermometers. The short and expressive word DIAL conveys the

idea of an immense advantage over the industrial thermometer, which is a local instrument. No matter how inaccessible the point of application of the bulb may be, the dial may be located where it cannot help being seen. It is worth nothing that one industry, comprising thousands of small establishments many of which are owned by persons of foreign birth, used very cheap thermometers or did without them until it awakened to the business value of modern methods, whereupon it began using pressure-spring dial thermometers. This industry today is a big market for modern temperature instruments.

Fig. 9. Five-inch dial armored flexible connecting tube, union connection bulb. (*C. J. Tagliabue Mfg. Co.*)

Fig. 10. Quadrant form, non-mercury liquid-filled, straight stem. (*Moto Meter Gauge & Equipment Corp.*)

Fig. 11. Duplex 8-in. dial for two temperatures, as "in" and "out" on feed water meters, economizer heat exchangers, unit heaters, etc. (*Foxboro Company.*)

Industrial Forms of Pressure-spring Indicating Thermometers.

Pressure-spring thermometers ordinarily embody a "tube system" consisting of a bulb, a flexible capillary connecting tube and a pressure spring which moves the pointer. This same tube system is found in non-electrical *recording* thermometers, whence the designation of both the dial thermometers and the recording thermometers as "pressure spring" thermometers, "metal bulb and capillary tube" thermometers or even "pressure gage" thermometers. The following paragraphs, table and notes are therefore applicable also to the *recording* thermometers which embody tube systems, and will not be repeated under "Recording Thermometers." This same remark applies to the automatic temperature controllers which embody tube systems.

While the maximum length of the connecting tube is limited by the filling of the system, there is no minimum length. Hence the "fixed stem" forms (Fig. 10) of pressure-spring thermometers (and the "room temperature" or "self-contained" forms of recorders). Fixed stem dial thermometers have in recent years been sold in large numbers for use on ice-cream freezers, on Diesel engines and on other industrial equipment where for various reasons they seem to have won preference over "industrial" thermometers. The majority of pressure-spring dial thermometers, however, are of the distance type.

The universally accepted classification is by the "filling" of the tube system. The original method (still used in some cases) was into numbered classes (I, II and III). The usual engineering designation of the three

classes today is "liquid expansion," "vapor-pressure" and "gas-filled." Without desire to invalidate the accepted classification into three classes, and merely for the convenience of the author and user of this Handbook, we may consider that there are four classes. The reason is that while the vapor-pressure and the gas-filled may each be conveniently described and studied as a class, the liquid expansion is different: It really consists of two sub-classes, mercury and liquids other than mercury. Such liquids may be water or various hydrocarbons, but actually 90% or more of the non-mercury liquid-expansion instruments in industrial use are filled with xylene (meta-xylene), $C_6 H_4 (CH_3)_2$, melting point —54°C, boiling point 139.2°C. The characteristics of the mercury instruments are so different from those of the xylene instruments that in describing the characteristics of pressure-spring thermometers we may well split the first class, and consider them all divided into Mercury, Xylene, Vapor-pressure and Gas-filled.

The principal characteristics of these four classes are set forth very briefly in Table II. Some notes are also added for the sake of amplification. Outside of the table and the set of notes, a few general statements remain to be made about pressure-spring instruments.

Centralization (Fig. 6) is made possible, for capillaries may be as long as 150 feet. Electrical instruments give a greater distance, but in many plants 150 feet is ample. On the other hand, the capillaries must not be cut, whereas no permanent injury is done by breaking an electrical conductor.

In addition to the information about scales in Table II, mention may be made of the possibility of *special scales*, which are impracticable with electrical instruments. Such special scales include the important kind produced by the *retard movements*. These scales are extremely valuable on processes where the "one best" temperature has been determined and is not subject to change. For example, in the pasteurization of milk, the temperature is often specified by legislation and inspectors check the records. An "open" scale is required around the pasteurizing temperature. Some states require a full $\frac{1}{16}''$ for each degree. The bulbs are subjected to the temperature of boiling water when the equipment is sterilized, so that the upper end of the scale must be, say, 220°F. Milk cooling temperatures must also be measured and this requires a lower limit at, say, 30°F. or a scale range of 190 degrees. $190 \times \frac{1}{16}''$ gives nearly 12", but various mechanical movements, practicable with pressure-spring thermometers, provide "milk scales" complying with the law but only 4" long.

Remarkable ingenuity has been displayed in meeting mechanical requirements while solving the problem of proper ratios of bulb volume, capillary volume and head volume. The importance of this problem with regard to accuracy may be illustrated by taking an exaggerated example of a pressure-spring thermometer (other than vapor-pressure) having a bulb volume of 10cc., a capillary volume of 10cc. and a pressure-spring volume of 10cc. Obviously, temperature variations at the head or along the capillary would cause a travel of the pointer equal to that produced by equal variations of temperature at the bulb. Fortunately this is an imaginary example. Capillary-to-bulb ratios are actually small enough, for short tubes at least, to minimize "tube error" as it is called.

Compensation for temperature fluctuations around the head of the system, containing the pressure-spring, is known as *head compensation* and is embodied in *all industrial* pressure-spring thermometers other than the vapor-pressure, where it is not required.

An exception to the exception implied by the last ten words of the above paragraph is furnished by vapor-pressure thermometers used for *refrigeration* work and made up in the distance form. That is to say, such thermometers are *not* an exception to the rule stated in the foregoing paragraph, and they may require head compensation. The explanation involves the "reversal" of such instruments. In brief, the normal "hot-water" range vapor-pressure system has its spring and capillary—and part of the bulb—filled with liquid. The bulb is the "hot spot" where the liquid "steams" and where the vapor-pressure is developed. For refrigeration applications, on the other hand, a liquid is chosen which vaporizes at room temperature and under the pressure used, but which *condenses* in the bulb. Therefore, the pressure-spring in the head of the instrument may act as a gas-filled bulb, if head temperature fluctuations are serious.

In refrigerator compartments, storage rooms, etc., where the entire instrument from head to bulb is subjected to the same temperature, no head compensation is required, no matter what class the instrument belongs to.

The *motive power* or pressure within the system is always an important consideration, for it must overcome friction sufficiently to minimize the friction errors, as well as variations in the force of the opposing hairspring, if any, and other such causes of error. In recorders, the friction of the pen on the paper chart must be negligible in comparison with the power developed. For these and other reasons all manufacturers provide an "initial" pressure within the system. (The working pressure, of course, increases with the temperature.) Initial pressures cannot be standardized for each class, because of several complications, among which may be mentioned the variety of the ranges called for by industrial process requirements. Both the length of the range in degrees, and its place on the scale of temperature (its "lower end") are factors determining the allowable as well as the desirable initial pressure. These initial pressures are not given in Table II but the statement may be ventured (subject to modification, as instruments are constantly being improved) that in the mercury class the initial pressure is greater than 2000 lb/in^2. In the xylene, it is 300 lb/in^2 for the water ranges and 250 lb/in^2 for refrigeration ranges. In the vapor-pressure class this pressure is probably about 100 lb/in^2; and in the gas-filled above 80 lb/in^2.

The motive power may be made to actuate the pointer, pen-arm, or other element, either *directly* or by means of intermediate *mechanical movements*. The direct indication method would seem to possess the advantage of simplicity, and other mechanical advantages, but impressive arguments in favor of various movements make manufacturers' sales literature interesting as well as instructive reading. The various mechanical methods by which pointers are actuated in dial thermometers do not deserve comparative discussion here. But the mechanism of a *recorder* is an important feature, and various movements will be illustrated and described under that heading.

Having discussed these things, it is now possible to discuss the *accuracy* of pressure-spring thermometers as a group, and of the classes within the group. As usual with all industrial temperature instruments, "proper installation counts more than intrinsic accuracy." This was said above, and it bears repetition. It may also be repeated, with reference to pressure-spring thermometers, that those on the market possess a greater intrinsic accuracy than conditions of industrial service call for in most cases.

TABLE II—CHARACTERISTICS OF CLASSES OF PRESSURE-SPRING THERMOMETERS

	LIQUID-EXPANSION		VAPOR-PRESSURE	GAS-FILLED
	MERCURY	XYLENE (m)		
"Filling"	Mercury under initial high pressure (Note a)	Xylene under moderate initial pressure	Volatile Liquid (Note j)	Inert gas under moderate pressure
Scale	Uniform	Uniform to 250° F., progressive above (Note e)	Progressive (Note k)	Uniform
Bulb Volume	Medium, and varies inversely with length of range	Very small (Note f)	Small	Large, and varies with *Tube* length
Minimum Bulb Length	3 to 5 inches	1 inch	2 inches	6 inches
Material	Steel	Brass, Monel or Nickel	Brass, Monel, Steel, etc.	Brass, Monel, Steel, etc.
Maximum Tube Length	25 feet (Note b)	75 feet	150 feet (Note l)	150 feet (Note p)
Sensitivity	"Medium"	"Good"	"Good"	"Poor"
Effects of temperature fluctuations along the capillary ("Tube error")	Vary with tube length and with area of capillary bore (Note c)	Vary with tube length (Note g)	None (Note m)	Vary with tube length and inversely with bulb volume (Note q)
Can effects of temperature fluctuations at spring be compensated	Yes	Yes (Note h)	Compensation unnecessary (Note m)	Yes
Effects of variations in atmospheric pressure (also "Altitude error")	None	None	Slight errors in lower end of range where actuating pressure is low	Slight errors at low working pressure only
Has difference of level of bulb and head any effect on calibration?	Yes—slight (Note d)	Yes—very slight (Note i)	Yes (Note n)	No
Lower limits of ranges	−38° C. (−36° F.)	−40° C. or F.	−30° C. (−22° F.) (Note o)	−130° C. (−266° F.)
Upper limits of ranges	538° C. (1000° F.)	400° C. (750° F.)	371° C. (700° F.) (Note o)	538° C. (1000° F.)
Usual maximum commercial length of range	538° C. (1000° F.)	333° C. (600° F.)	140° C. (250° F.) (Note o)	550° C. (810° F.)
Usual minimum commercial length of range	25° C. (45° F.)	22° C. (40° F.)	50° C. (90° F.) (Note o)	50° C. (90° F.)

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NOTES

(*General Note*)—Table II is without precedent. It had to be compiled, in part, from information released for the first time by various qualified sources. In many cases the author had to use his own judgment in giving the briefest possible "answers" to the "questions" implied in the first column. As is always the case when compiled and "averaged" information is published for the first time, the possibility of departure from strict accuracy is unavoidable. It is hoped that this possibility is not an actuality in any of the 60 "answers" to the 15 "questions"—nor in any of the notes below. No effort was spared to make the information in the table and in the notes complete, accurate, and, above all, impartial. The author will be glad to hear from all interested parties.

(a)—The greatest advantages of the high pressure mercury filling are ruggedness, durability and permanent accuracy. It requires the use of steel, for the mercury would amalgamate with other common metals. A slight disadvantage is that the bulb must often be enclosed in a separable socket or otherwise protected to resist corrosive conditions. This increases the lag, and the greater amount of metal also conducts heat to the outside of the apparatus. For that reason, whenever there is room, long sockets should be specified.

(b)—150 feet or more when a method of "full compensation" is used. For this purpose one manufacturer uses a double connecting tube, the inner capillary containing the mercury and the space between being filled with gas. This gas-filled space acts as a bulb connected to a second pressure-spring in the case—the spring shifting the fulcrum of the mercury mechanism to compensate for any temperature fluctuations along the tube.

(c)—No effects when "full compensation" method is embodied in the system.

(d)—True enough, 13.6 times the hydrostatic pressure of water (about 15 times that of hydrocarbons) for same altitude difference, BUT—tube lengths limited AND working pressure from one to three *tons* per square inch. Hence, "slight."

(e)—Non-linearity above 250°F is very slight and can be accurately reproduced; therefore, printed recorder charts may be used.

(f)—But not as a cursory cubing would lead one to believe. In other words, for bulb *lengths* of 1", 2", 3" and 6", volumes are NOT in ratio of 1, 8, 27, and 216. Actual case study: comparison of xylene with the other liquid-expansion class showed xylene bulb volume one-fourth mercury bulb volume for a given range and for actual instruments on the market, a xylene spring direct-connected, and a mercury spring plus a mechanical movement for obtaining equal angular travel by multiplying spring deflection.

(g)—Slight: Even with smallest bulb, effect of change from ice to steam on 10 ft. capillary produces only 1°F error in indicating bulb temperature.

(h)—Compensating device is within area formed by outside diameter and height of spring.

(i)—Lowest working pressure, at low end of usual ranges, is 300 lb/in²; 10 ft. head of xylene = 3.5 lb./in².

(j)—Manufacturers have studied the characteristics of many volatile liquids, and supplied the proper filling for each range specified. It is always advisable to specify not only the range but the zone within the range where accuracy is most needed. The reason is that the sensitivity of an instrument embodying a vapor pressure tube system increases with the temperature.

(k)—A "progressive" scale is one which is "closed" at its lower end and "open" at its upper end. Such scales are necessary by reason of the non-linearity of vapor pressure with temperature, unless by the use of a suitably shaped cam or other movement the uncoiling of the spring can be made to produce a uniform motion of the pointer for every degree throughout the entire range.

(l)—The only tube length limitation arises from slight fluid friction and consequent time lag or sluggishness—the connecting tube and spring for the usual "hot water" ranges being completely filled with unvaporized liquid, with vapor generated only within the bulb. On some control applications, where corrections should not be made too quickly, longer tube lengths may be used.

(m)—On most applications the bulb temperature is higher than the air temperature. Vapor is generated only within the bulb and the effects of fluctuations along the tube on the *volume* of liquid in the tube and spring are negligible. However, when any portion of the connecting tube is subjected to a higher temperature than that of the bulb, accuracy is destroyed, for the spring reacts to the pressure of the higher temperature as long as there is any liquid exposed to the hot spot. In time the liquid is driven away from it and equilibrium is established. That is why a "steady hot spot" may sometimes be compensated for. Just imagine that the system is filled with *water* and the bulb with water and *steam*, and the whole "mystery" vanishes!

(n)—Considerable when working pressure is low. 10 ft. water head = 4.33 lb/in². Assuming a high Baumé hydrocarbon, we get about 3.5 lb/in.² for every 10 ft.

(o)—The temperature range characteristics depend on the liquid used. In order to obtain the highest possible accuracy, liquids are chosen which will produce a vapor pressure sufficient to assure sensitivity at the lower end of the specified range. The upper end naturally depends on the critical temperature and critical pressure. As a rule, vapor-pressure thermometers give the best results when the length of the range is within the limits specified in the table. This is simply based on the availability of special liquids. Suggestions for "new" liquids are frequently received from chemists but in most cases such liquids, while making longer ranges possible, possess undesirable characteristics such as instability, chemical action on the metals used for bulbs, tubes and springs, etc.

(p)—Fluid friction in the connecting tube does not cause much lag, the medium being a gas, and the length limitation is imposed by the fact that temperature fluctuations introduce large errors. In plants provided with room temperature control, longer tube lengths may be used.

(q)—The largest practicable volume of gas should always be contained within the bulb and therefore the longest length which the applications can take should be specified, so that the manufacturer may supply the longest bulb within this restriction.

The *intrinsic* accuracy of pressure-spring thermometers depends on several factors which are well known to the manufacturers. Each factor produces an inevitable *inaccuracy* amounting to a maximum value of from 1/20% to 1/5% of the range specified—say an average maximum of 1/10%. The errors produced by these factors are additive, of course. Depending on the particular construction, there are from three to five such factors, so that their largest sum (when each of them produces its average maximum error of 1/10%) is 5/10% of the range.

These are inevitable factors, inherent in the design and construction, and in the materials used, which an experienced designer with scientific training could predict and roughly evaluate on examining the blueprints and the specifications of materials. In addition there are causes of inaccuracy arising from the impossibility of manufacturing perfect instruments. These causes are not necessarily additive, and as for the maximum inaccuracy which they may produce, no use discussing it—if it exceeds the inspection department's requirements, the instrument is not put in stock.

One such cause of inaccuracy—and one only—deserves a little discussion here. We refer to the imperfection of springs. There is no such thing as a perfect spring—spiral, helical, volute, Bourdon, diaphragm, bellows, capsular, etc. Nevertheless, instrument designers and metallurgists, after working together for years, have developed quantity-production springs that show excellent pressure-deflection graphs—uniform to a split hair and with hysterisis loops no thicker than a soft pencil line on a letter-size sheet of co-ordinate paper. With such springs you cannot detect errors with the naked eye even when the pointer travels across a stamped scale or the pen across a printed chart . . . *while the springs are young!* For it is a sad fact that thermometer springs are subjected to such severe service that they age in the course of time. True, a watch hair spring may oscillate millions of times and still help the watch keep good time, but this is not a fair comparison. In the first place, the variations in the elasticity of a hair spring are largely compensated by the isochronous dead-beat escapement and balance wheel. In the second place the area stresses in thermometer springs are much greater fractions of the elastic limit. This is the unavoidable price of sensitivity: Sensitivity must depend on the amount of *spring deflection* per unit change in temperature, for if multiplication (mechanical movements) or magnification (long pointers) are carried too far, they impair *accuracy* by accentuating both hysterisis and non-linearity.

While the results of laboratory accelerated-fatigue tests are not always fully conclusive, it may be mentioned that one series of such tests, conducted

several years ago by a company that uses thousands of pressure-spring thermometers, tended to show that all springs fatigue and eventually become highly irregular in their response; also that some designs, constructions and materials are better than others in regard to fatigue and permanent set.

The accuracy-life of pressure-spring thermometers is never reckoned in millions of full swings across the scale, seldom in hundreds of thousands, more often in tens of thousands, and there's no use concealing the fact that here and there some individual thermometers sometimes become erratic after several thousand (or fewer) hot-cold alternations.

All of which prompts two general statements on this subject:

1. *"Complicated" vs. "simple" movements.* When non-linearity sets in, there is nothing to be done about it in a direct-connected spring-and-pointer instrument; but in its effects may be minimized (or sometimes fully corrected) by a system of adjustments, necessarily comprising a plurality of screws, levers, bearings, and other such elements which, of course, *may* wear, collect dust, etc. . . . It's not a "choice of two evils," though, for the errors we speak of—both of fatigue and of wear—are seldom of consequence in industrial work until long after the instrument has paid for itself.

2. *The choice* of any construction should rest on the intended use of the instrument: If for a small part of the range, the simplest forms may do, because any thermometer may be adjusted for accuracy at *one* point. If permanent accuracy to within 1% is desired throughout the range, the wisest investment may turn out to be an instrument of higher first cost and which requires careful attention every few months or so.

Inaccuracies resulting from careless specifications when ordering give the greatest trouble in service. There is no space here for a complete set of recommendations, which moreover should be unnecessary to any engineer that studies these pages, including Table II and the notes. Just one example, though: In specifying a gas-filled pressure-spring thermometer get the largest available and convenient bulb volume, and specify the minimum usable tube length regardless of hazy possibility of future use on another application calling for a longer tube. And always remember that any thermometer measures the temperature of its bulb. For a walled or jacketed application don't save a few dollars and get a bulb so short that it will measure the temperature of the wall and not of the flue gases or whatever there is within the enclosure.

The possible effects of accidental breakage may be of interest to the process man. A gas-filled system can be smashed by a clumsy workman without the escaping gas harming machinery or equipment or contaminating edible products, chemical mixtures, etc., since inert gases are commonly used. The same cannot be said of other fillings.

Table II gives the *material* with special reference to the *bulbs*. While any bulb may be protected by a *separable socket* of any metal or alloy, and while it may be lead-covered, or tinned, or plated with chromium or other metals, the *capillary must not be forgotten*. The capillary may be protected by any one of a great variety of tubings or armors—spiral, woven, lead, etc. etc. The exposure of the tube to destructive influence is sometimes overlooked in specifying the instrument, resulting in the "premature death" of instruments that should give many years of satisfactory service. The strength of the tubing—whether single or combined—is another consideration. Mention may be made of the unique phosphor-bronze capillary tubing, standard with one manufacturer, which is originally round in cross

section, then squeezed to a square, then the sides of the square are squeezed in, resulting in a "four-pointed star" cross section, producing a very small bore area and increasing flexibility without (it is claimed) decreasing strength.

Bulbs, Sockets, and Connections—All of the ingenious styles described above under "Industrial Thermometers" are available with pressure-spring thermometers, except such styles as "bare-bulb" and others peculiar to industrial glass thermometry. In addition, there are "long capillary" bulbs applicable to rooms, ovens drying compartments, etc., and other styles possible only with distance thermometers. Among these latter may be mentioned the "bendable extension" allowing the bulb to be out of line with the axis of the pipe-thread connection, the elbow connections (plain or with lead-covered funnel for corrosive exposure) and special bulbs, sockets, and connections for various specific industrial applications.

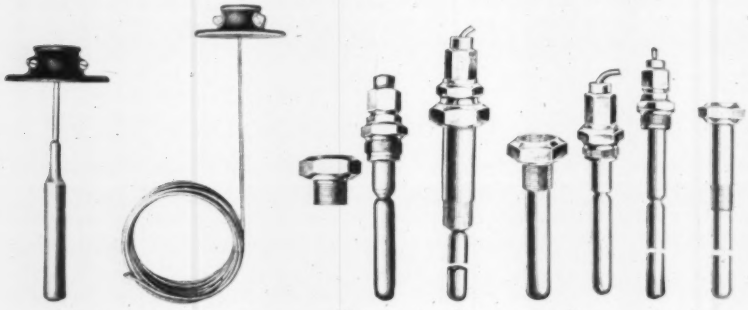

Fig. 12. Principal Forms of Bulbs, Connections and Sockets for Industrial Pressure-Spring Thermometers. (*Taylor Instrument Companies.*)

Illustrations show products of one manufacturer but following discussion applies to various makes. (A) Plain bulb, adjustable clamp flange by means of which bulb may be positioned any distance from wall or cover through which tube is passed. Suitable for air and gas temperatures when circulation is adequate, but mostly used for tanks—being inserted from top. The flange may be replaced by an adjustable ("split") union connection hub for insertion through the top of such equipment as pasteurizers, etc., where sides and bottom are steam-jacketed. The bendable extension bulb is similar in appearance but the distance from connection to bulb is not adjustable and the connection is pressure-tight. (B) Long capillary bulb, sometimes known as super-sensitive, sometimes formed as a helix with a stiffening rod at the axis, for air or gas temperatures. When vapor pressure, "hottest spot" temperature above pressure-spring; liquid expansion or gas filled, bulb "averages" temperature. (C) Union connection—most popular fitting—permitting easy installation wherever S. P. T. can be tapped. (D) Same, but with extension neck between pipe thread and hex for use on lagged equipment. (E) Separable socket connection. Remains pressure-tight when bulb is withdrawn and protects bulb from corrosion, etc. (F) Same, but with extension neck.

e. Solid Expansion

Expansion thermometers are also known as metallic or bi-metallic or mechanical thermometers: also (but erroneously) as "pyrometers." The common form is straight stem and dial, the face of the dial being perpendicular to the stem, or at an angle to it, or in line with it. The differential expansion principle is employed, two rods or tubes being used. In the bi-metallic type the rods are of metals with different coefficients of expansion. The metal-and-refractory type is described by its name. These instruments are losing their popularity with the adoption of more reliable thermometers. They should never be used above a dark red heat which is at all visible in daylight and, needless to say, the entire stem should be exposed to the measured temperature. They soon become very inaccurate.

The principle of differential expansion is employed in sensitive instruments of quite a different form—the bi-metallic element being in the form of a tiny delicate spiral. This is the principle of the Bréguet thermometer

which, however, is seldom used on industrial applications. A minute bi-metallic spiral is likewise sometimes employed in radiation pyrometry, being usually located at the focus of a lens or mirror.

In thermostats differential expansion primary elements perform their function quite satisfactorily, dependability of response being more important than permanent accuracy of indication.

f. Resistance Thermometers

Comparison with Other Thermometers—This last group in the thermometer division possesses one important advantage over the other groups: the primary element may be disconnected from the indicating element. Therefore a number of resistance coils ("bulbs") placed in widely separated locations may be successively connected to one electrical measuring instrument which serves as the temperature indicator. This centralization is of importance in industrial work where comparisons of temperatures are desirable at a moment's notice. In cold storage work 30 or more bulbs are not uncommon for a single indicating instrument. It also is possible to obtain instruments so calibrated that direct readings can be taken showing either (a) the average temperature of two or more points, or (b) the difference in temperature between two points.

The lowest temperature accurately measurable with industrial forms of resistance thermometers is about −165°C (−330°F); the highest about 700°C (1300°F).

The intrinsic accuracy of the resistance thermometer is very high (under laboratory conditions the resistance thermometer is used as the International Standard between −190°C and 660°C) but it is more complicated than mercurial or pressure spring thermometers and therefore industrial service may cause large errors through poor contacts, rough handling, deterioration or contamination of the platinum, defective insulation and other causes difficult to prevent altogether in plant service. Resistance thermometers should preferably be in charge of men with some electrical training. In the hands of such men, and when the precautions recommended by the manufacturers are taken, the accuracy of indication will be higher than that of any other group of industrial temperature indicating instruments. It is stated by one manufacturer than "at 32°F, at which temperature the resistance of each thermometer is adjusted, the accuracy is ±1/10°F."

The exact place, or relative importance, of the resistance thermometer is still a subject of controversy. On the one hand, we read in the U. S. Bureau of Standards Technologic Paper No. 170 (page 133) that "its importance for industrial processes at high temperatures is waning." This paper was issued in 1921. On the other hand, the 14th (1929) edition of the Encyclopaedia Britannica states (Vol. XXII, Page 120) that it "bids fair to surpass all others in the variety and accuracy of its applications."

In a plant or department where no electrical temperature instruments have ever been used, the acquisition of the first resistance thermometer meets with "sales resistance" if for no other reason than the fact that a complete resistance thermometer set usually includes (a) one or more bulbs, (b) a single or multiple point bridge, with proper switch arrangement, (c) a lead adjustment coil (sometimes included in the bridge box), (d) a high grade storage battery holding a constant voltage so that adjustments will not be required oftener than every 24 hours, and finally (e) the electrical instrument itself. To engineers unfamiliar with resistance thermometry

the mere thought of looking after this apparently complex outfit is a deterrent. In reality, no engineer need hesitate.

Where accurate temperature measurement is necessary, as in steam work, calorimetry, determination of optimum process temperatures, etc., most engineers are in the habit of resorting to the etched stem laboratory thermometer (immersed in a mercury well, when pressure is a factor)—sometimes forgetting that the mercury-in-glass method of thermometry is subject to errors and requires corrections, whereas resistance thermometry would seem to be preferable, as will be seen by the following comparison:

1. *Stem Exposure*—The reading of a platinum thermometer with compensated leads depends only on the temperature of the coil and not on the temperature of the stem, provided that the immersion is sufficient to avoid errors due to conduction or convection along the stem.

2. *Aging effects* of mercurial thermometers arise chiefly from the small expansibility of mercury combined with the relative instability of the glass tube. In platinum thermometry, the tube of quartz or other material, which contains the coil, has nothing to do with the reading, and the effect of any possible strain of the fine wire of the coil in minimized by its small dimensions and by the large temperature-coefficient of the increase of resistance, which is more than twenty times greater than the coefficient of apparent expansion of mercury in glass. It is not surprising, therefore, that zero creep of a platinum thermometer should be practically negligible, provided that the wire is not strained or contaminated. With ordinary care, changes of zero due to exposure to any given limits of temperature are *less than the limit of accuracy of observation.*

3. *Pressure Correction.*—The effect of change of pressure on a platinum thermometer of the ordinary tube form is of course nothing, as the wire itself is not exposed to the pressure. Even if the wire is naked and directly exposed to large changes of pressure, the change of reading is negligible. The only source of error "analogous" to the irremediable effects of capillarity which are troublesome with delicate mercurial thermometers, is the friction of the pivoted moving coil used in some makes, but this is seldom troublesome and generally remediable.

Primary Elements or Bulbs—(See Figs. 13 to 19)—The operation of a resistance thermometer depends upon the variation with temperature of the resistance of an electrical conductor. The primary element, responding to temperature, is a resistance coil or "spiral." This coil, together with its frame, tube and other necessary accessories, is itself called the "thermometer" in some publications, but in industrial work the entire primary element may simply be called the "bulb." For industrial service, the coils are made of platinum, of nickel which (in some forms only) is fairly satisfactory for temperatures up to 300°C (570°F), and even of copper. In a common form of 8-ohm platinum coil, fine wire is wound upon a frame made of crossed strips of thin mica notched at the edges to hold the wire in place. From the ends of this coil, lead wires of platinum or gold are carried to the "terminal head" where the binding posts are fixed. The lead wires are insulated and held apart by mica disks through which the wires are threaded, and which serve to minimize convection. The coil is protected by a porcelain or quartz tube which fits into the terminal head. For industrial use the refractory tube itself may be enclosed in a strong sheath or well as in the case of "industrial" and pressure-spring thermometer bulbs which are enclosed in bulb chambers and separable sockets. In another form, a 50-ohm coil of fine platinum wire is wound upon a fused quartz rod and fused inside a quartz tube, so that the platinum is entirely embedded in quartz. Gold leads are carried from the coil to the terminal head. The fused quartz insures high electrical insulation, while still preserving excellent heat conduction. This form of bulb is very compact, and the platinum is thoroughly protected against deterioration. Transparent fused quartz is unattacked by most acids except hydrofluoric. It may be subjected to the most violent temperature changes without cracking. Its dielectric strength, unlike

most porcelain, is but very slightly lowered when heated to high temperatures.

The variety of primary elements actually on the market for industrial applications is so great that space limitations prevent even a classification. Suitable bulbs are available for indoor or outdoor atmospheric temperature, refrigeration work, steam work, electric transformers, ovens, dryers, bearings, oil baths and other metallurgical applications, etc. Copper-nickel tubes, round or flattened, are available for feed water heaters or lines. Separable sockets, in which a number of bulbs are interchangeable and which themselves have standard thread or flange connections, are used against corrosive conditions, against pressure up to 1500 pounds or higher, etc.

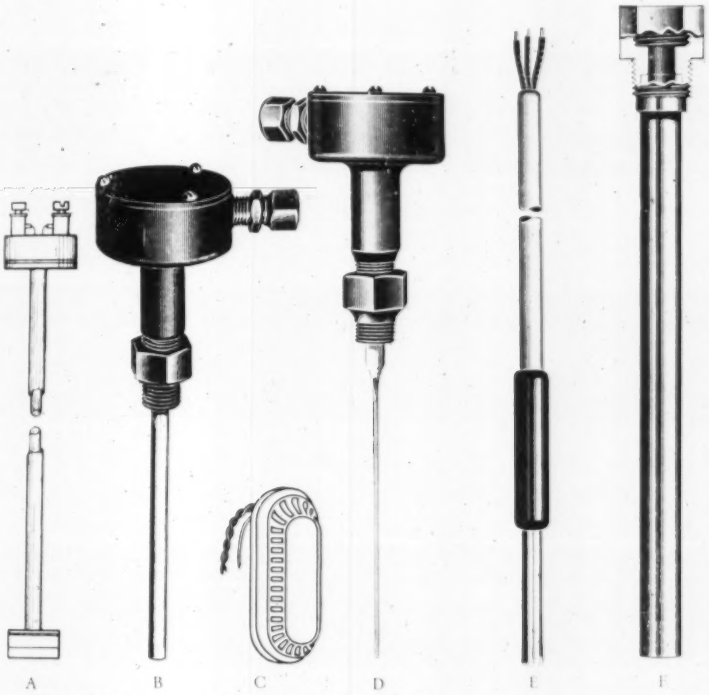

Fig. 13. Typical Industrial Forms of Resistance Bulbs, etc.
(A) Contact Plate "Bulb" for Bearings, Insulation, Hot Plates, etc. (*Chas. Engelhard, Inc.*) (B) Protected Nickel Coil Bulb. (*Leeds & Northrup Company*) (C) Wall Type Sensitive Bulb for Room Temperature. (*Wilson-Maeulen Co., Inc.*) (D) Flattened Protecting Tube Bulb. (*Leeds & Northrup Company*) (E) Nickel Coil Bulb with Rubber-Covered Leads. (*Leeds & Northrup Company*) (F) Separable Well or Socket. (*Leeds & Northrup Company*)

Lead Systems—Two, three or four binding posts on terminal heads, or cables issuing from the outlet, of the various forms of bulbs, always interest the student, often puzzle the prospective purchaser; and the different methods of which they are the visible embodiment give rise to interesting discussions pro and con. The choice should not depend upon prejudice but upon the precision desired, the distance from bulb to indicator, the working range and other requirements of each application. Space does not allow even summarized discussions pro and con. The following is a brief and excellent exposition of the subject by the Bureau of Standards:

If only two lead wires are carried from the thermometer coil to the indicator, the resistance measured is the sum of the resistance of the coil, the platinum or gold lead wires to the head of the thermometer, and the copper lead wires from this point to the indicator. The resistance of the platinum or gold lead wires will depend upon the form of temperature gradient along the thermometer from the bulb to the head and upon the depth of immersion. Hence this variable resistance is introduced into the temperature measurement, and changes in the resistance of the lead wires will be interpreted as changes in the temperature of the thermometer coil. There are three general methods for minimizing or eliminating the effect of variation in lead resistance.

1. *Use of a Coil of High Resistance*—The resistance of the lead wires from the coil to the thermometer head and the variation in resistance of the copper lead wires are small compared to a 50-ohm platinum coil. Hence such variations in resistance as are likely to occur do not introduce serious error. Thus, only two lead wires are necessary, from the thermometer to the indicating instrument.

2. *Compensating Lead Wires of the Callendar or Siemens Form*—Both of these methods of compensation are applicable to measurements made with the Wheatstone bridge. The Callendar form of compensation requires four lead wires. Two of the lead wires joined to the end of the coil are connected in one arm of the bridge, and the other two lead wires, which are "dummy" leads formed of a single loop of wire extending to the top of the coil, are connected in the corresponding arm of the bridge. The two sets of lead wires are alike, so that variations in temperature affect each set similarly. The Siemens method of compensation requires three leads and is more often employed industrially in this country.

3. *Potential Terminals*—The use of potential terminals is necessary when the resistance of the thermometer is made very low or when the precision required is such as to make variations in difference of lead resistances inadmissible.

Indicating Systems—The measurement of the temperature to which a resistance bulb is exposed is simply a matter of measuring its resistance. Electrically, a number of methods are possible. Practically, owing to the need of some system of lead compensation and in order to have the temperature indicated on a convenient instrument, the methods are limited to a few. The ultimate indicating instruments are usually of standard forms applicable

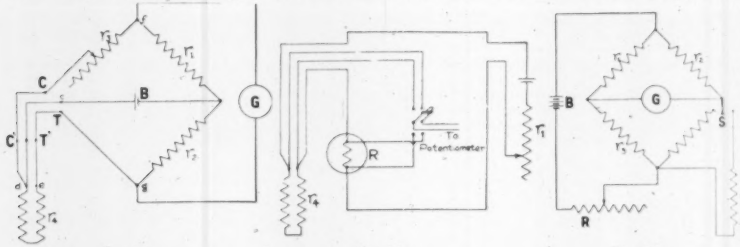

Fig. 14 Fig. 15 Fig. 16

LEAD SYSTEMS FOR ELECTRICAL RESISTANCE THERMOMETERS
(Reproduced from Bureau of Standards Technologic Paper No. 170)

to other purposes than resistance thermometry. On the other hand, the indicating systems, or "methods," of which these instruments constitute the last element, are, in modern practice, especially worked out for resistance thermometry. Here again, since there are pros and cons, it is well to quote from the Bureau of Standards:

1. *Three-Lead Wheatstone Bridge Method*—Fig. 14 illustrates the wiring diagram for a simple Wheatstone bridge and thermometer with the Siemens three-lead compensation. The platinum or gold lead wires C′d and T′e in the thermometer are constructed of as nearly the same resistance as possible and the copper lead wires CC′ and TT′ must also be of equal resistance. The battery B is connected between the ratio arms r_1 and r_2 of the bridge and to the compensation lead wire cd. A sensitive galvanometer G is connected to the points f and g, as illustrated. By changing r_3 the bridge is balanced until the galvanometer shows zero deflection. Whence from the principle of the balanced Wheatstone bridge we obtain the following relation:

$$\frac{r_3 + C'd}{r_1} = \frac{r_4 + T'e}{r_2}$$

If r_3 is constructed equal to r_2 then since Cd = Te, $r_4 = r_1$. Hence the measured resistance is independent of the resistance of the lead wires.

2. *Four-Lead Potentiometric Method*—Fig. 15 illustrates the wiring diagram for a four-lead thermometer used with a potentiometer. The current, adjusted to a suitable value by the rheostat r_1, flows through a resistance standard R and the thermometer coil r_4. The potential drops across R and r_4 are measured by the potentiometer. Whence from Ohm's law, $\frac{e}{R} = \frac{e'}{r_4}$ where e and e′, are the potential drops across R and r_4 respectively. Thus, knowing e, e′, and R, the coil resistance r_4 is readily obtained. The resistance R may be made adjustable, so that by varying R until $e = e'$ the dial setting gives directly the value of $r_4 = R$. This method is useful in precise laboratory work.

3. *Deflection-Galvanometer Method*—The bridge methods so far described require the adjustment of the bridge until the galvanometer shows zero deflection. The temperature is then read from the setting of the dial or slide wire. It is possible, however, to use an unbalanced bridge with all resistances fixed, except that of the thermometer, which depends upon its temperature, and the temperature is obtained from the scale reading of the galvanometer. Fig. 16 shows the wiring diagram for an unbalanced Wheatstone bridge. With the switch S thrown to the right we have the simple Wheatstone bridge, except that the resistances r_1, r_2 and r_3 are fixed. At a certain temperature of the thermometer—for example, 10°C—its resistance is such that the bridge is balanced and $\frac{r_4}{r_1} = \frac{r_3}{r_2}$. If the temperature of the thermometer increases, its resistance increases and the bridge is no longer balanced. Thus a current flows through the galvanometer, producing a deflection. In general, the deflection of the galvanometer depends upon two factors—the temperature of the thermometer and the current flowing from the battery B. This current is adjusted to a definite value in the following manner. The switch S is thrown to the left, thus replacing the thermometer by a fixed resistance of such magnitude that suitable value of the current from B deflects the galvanometer to its full scale deflection or to a normal point marked on the scale. The resistance R is adjusted until the galvanometer deflects the proper amount. The switch is then thrown to the right, and, since the factor of variable battery e. m. f. or current is eliminated by this preliminary setting, the scale of the galvanometer may be empirically graduated to read directly the temperature of the thermometer. Thus no further adjustments are necessary as long as this current remains at the proper value, and any temperature is readily observed without the necessity for balancing required in the ordinary bridge. It is possible to have two or more temperature scales on the galvanometer. When two scales are provided—as, for example, 0° to 300°C and 300° to 700°C—one of the arms of the bridge is made adjustable to either of two resistances, one giving zero deflection for a thermometer temperature of 0°C and the other zero deflection for a temperature of 300°C.

Indicators—The average industrial engineer has probably skipped the immediately foregoing descriptions. No matter. Having decided upon the use of a resistance thermometer for any particular application, and having described the conditions and his requirements to the thermometer manufacturer, he may leave the selection of the proper method to the latter, knowing that the reading on the indicator scale will be the actual temperature of the bulb. Indicators are standardized electrical instruments and this is no place to discuss damping, torque, air gaps, zero creep, etc. The appearance of well-known makes is shown in Figs. 17 to 20.

Fig. 17 (above)
Leeds & Northrup Company

Fig. 18 (left)
Wilson-Maeulen Company, Inc.

Fig. 19 (above)
Brown Instrument Company

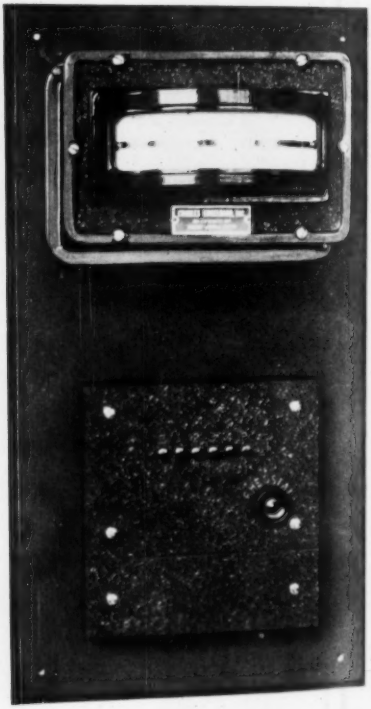

Fig. 20 (right)
Chas. Engelhard, Inc.

TYPICAL INDUSTRIAL FORMS OF INDICATORS USED IN CONNECTION WITH ELECTRICAL RESISTANCE THERMOMETERS

Measurements
Industrial & Scientific
An Instruction Book for Engineers

DR. WALTER BLOCK
Eichungsdirektor der Provinz Ostpreussen

CHAPTER II. GENERAL REMARKS ON MEASUREMENTS AND THEIR MANIPULATION

1. Accuracy, Errors in Measurement and Reliability of Measurements.

To carry out a measurement means nothing more than to compare one quantity with another one similar to the first. For example in measuring a length, one compares it with a given standard length which is usually represented by a rule. If the volume of a container is determined it is compared with the volume given by the division of a measuring cylinder or by weighing with water whereby use is made of the known relation between volume and mass. In the same manner, if one wants to determine a temperature it is compared with the standard temperature indicated by a thermometer, and finally if heating values are to be determined this is done by comparing in the calorimeter the substance of unknown heating value with a substance of known heating value, or, more specifically, by investigating the substance for its amount and heat quantity produced and then again determining the quantity of heat produced by a temperature measurement as before, and by determining the quantity of the calorimeter substance. For the latter, the knowledge of the specific heat of the calorimeter material is also required which is either known a priori or can definitely be determined by a special test by determining a quantity and measuring a temperature. Therefore, 2 kinds of measurements can be distinguished, direct measurements and indirect measurements. As examples may serve the measurement of a length and the determination of a heating value respectively.

For all measurement, it is, therefore necessary to have at one's disposal standards. The nature of these standards is determined by the kind of measurement, and the result of the measurement depends for its accuracy on the reliability of the standards. For instance, it is quite obvious in the measurement of lengths even if it is a question of quite simple measurements, that each error of the standard enters the result in its full value. As everyone knows it is usual, and also self-evident for more correct measurements, that each measurement be repeated several times if importance is placed on its reliability. But if the same length is repeatedly compared with the same incorrect rule it is natural that all measurements are in error in an equal manner. A proof for this statement need not be given. The same holds for any weighing. The case becomes a little more difficult if it is a question of an indirect measurement, or in other words, if several single measurements or several measured quantities are used jointly for making the measurement. Each single measurement must then be carefully studied to determine how much the result is influenced by errors in the standards. This will be discussed in more detail later.

As already pointed out each measurement is a comparison with other quantities which is carried out experimentally and therefore can not be wholly without error. Each measurement is influenced by uncertainties

of observation. It is clear that no length can be determined more accurately than the standard permits, and it is likewise also known that in more delicate weighings errors occur due to the scale and weights. If a substance is weighed several times, under different ambient conditions, as for instance different temperature, different air pressure, etc., different results are also obtained in the conversions to same temperature and pressure, because the outer conditions can not be taken into account fully in the calculations. Generally speaking, therefore, if the same quantity and the same amount of a substance is weighed repeatedly different results will be obtained, each time according to the prevailing conditions, and all values will be grouped with more or less reliability around an average value. The deviations from this average will, in this particular case, be due to the use of different sets of weights which are perhaps not quite accurate, to errors of the balance, and to the exterior conditions which can falsify the measurements, and it will in all probability be possible to say, if no special reasons exist, that all individual measurements in themselves have the same claim to accuracy. The practical procedure is, therefore, to take the average of all individual measurements and regard this average as the final result of the measurements. The deviations of the individual values from this average value then give an indication for the degree of reliability of the measurement.

It is a general rule which seems to be fully justified that each measurement which, is expressed by figures is given numerically in so many significant figures that the last figure is still fairly correct. Care must be taken that all figures have equal value and that a cipher has the same importance as every other. It is therefore not permissable to omit one or several ciphers at the end of a number. If the result of a measurement is simply given by 3, for example that a body weighs 3 g then this means something quite different than if this figure would be given as 3.000. In the first case the figure would mean that the body weighs about 3 g, in fact perhaps only 2 g or even 4 g, in the other case it is to be indicated that the body very likely is only a few milligrams heavier or lighter than 3 g if none of the usual information on the accuracy is given as is often required. It must, therefore, be made an absolute rule for all measurements that the measured quantity is given in so many figures that the last figure of the result still appears fairly reliable. If in the usual chemcial analyses more than five places are given, for example in the analysis of a spring water, it can be said in the beginning that such a measurement implies a degree of accuracy which is by no means justified. If as is shown below, one finds the complete analysis of a mineral spring which contains the several substances in greatly varying amounts, and if the errors of the analysis with respect to the individual substances are simply filled with meaningless ciphers, such procedure can not be recognized by experts.

It can be assumed with certainty even without knowing in detail the manner of carrying out the analysis, that the figures under 1), 3), 5), 8), 10), 11), 12), are fairly correct as regards their actual value. 2) may have been altered by addition of a cipher and made consequently apparently more correct than is the case. 4) seems to be calculated too exactly. The same holds true for 6), 7), and 9) to a much greater extent because the calculation of the analysis has been carried out very likely with too many figures. The final cipher in 13) obviously has no foundation.

The indications would be objectively justifiable in the form given in the last column even though the last numbers might still be sufficiently unre-

Example of a misleading analysis of a spring water

1000 parts contain	Temperature 9.6°C	Corrected compare below
1) Potassium Sulphate	0.007402	0.007402
2) Sodium Sulphate	0.022830	0.02283
3) Sodium chloride	0.005030	0.005030
4) Bicarbonate of soda	0.023047	0.02305
5) Bicarbonate of lithium	0.000626	0.000626
6) Calcium Bicarbonate	0.740450	0.7404
7) Bicarbonate of magnesia	0.526240	0.5262
8) Bicarbonate of manganese	0.002923	0.002923
9) Iron Bicarbonate	0.013800	0.01380
10) Calcium phosphate	0.000560	0.000560
11) Aluminum phosphate	0.000240	0.000240
12) Siliceous earth	0.006350	0.006350
Total	1.349498	1.349
13) Carbon dioxide, free	2.593000	2.593
	3.942498	3.942

liable. Without seriously influencing the result, the last numbers can be omitted in all figures.

Such analyses are found continually.

If one desires a guarantee as to the accuracy of a measurement, the respective quantity must have been measured a number of times. The average value of the various measurements is taken and the deviation of the individual results from this average calculated. The theoretical treatment of the influence of errors was given by the mathematician Gauss, and only the most necessary shall be given here in brief without further proof.

If, in the example below, the same quantity has been measured 10 times

Example of a measurement of a length in mm repeated 10 times under the same conditions

	Deviation from average	square
13142	0	0
45	+3	9
37	−5	25
39	−3	9
44	+2	4
41	−1	1
43	+1	1
44	+2	4
38	−4	16
45	+3	9
13142		S = 72

under the same conditions, and the average value of 13142 calculated from these 10 measurements, the deviations from the average are determined with their signs and so the differences of the individual values from the average are obtained. According to Gauss, these deviations are then squared which eliminates the influence of the signs. The sum of these squares of errors designated as S = 72, is then the value to be used for further calculations. The so-called mean error of an individual measurement is expressed, accord-

ing to Gauss by the formula

$$\epsilon = \pm\sqrt{\frac{S}{n-1}}$$

and the mean error of the result by the similar formula

$$E = \pm\sqrt{\frac{S}{n(n-1)}} = \frac{\epsilon}{\sqrt{n}}.$$

In the present case, therefore, since the number of individual measurements was assumed as 10 the mean error of the individual measurement amounts to

$$\epsilon = \pm\sqrt{\frac{72}{9}} = \pm\sqrt{8} = \pm 2.8 \text{ mm}$$

and the mean error of the result to

$$E = \pm\sqrt{\frac{72}{10 \cdot 9}} = \pm\sqrt{\frac{72}{90}} = \pm\sqrt{0.8} = \pm 0.9 \text{ mm}.$$

It is self-evident that in measuring the same quantity repeatedly or, better, very frequently, the individual values in greater number lie close to the average, and that only in rare cases do they differ greatly from the average. That is, the probability of obtaining greater deviations from the average i.e. to commit larger errors, is comparatively less than to obtain smaller errors of measurement. From the formulae given above it follows directly that it is possible only with difficulty to reduce the error by accumulation of measurements. If one wants to obtain an accuracy of measurement which can also be guaranteed for a single individual measurement, actually 100 measurements must be made in order to obtain a tenfold accuracy of measurement.

The above mentioned error is designated as mean error. Very often instead of the latter the so-called probable error* is given which is defined so that with equal probability an actual error is committed which is greater or smaller than the given value. Correspondingly, the probable errors of the individual measurement and the result are about

$$\epsilon' = \pm\frac{2}{3}\sqrt{\frac{S}{n-1}} \quad \text{respectively} \quad E' = \pm\frac{2}{3}\sqrt{\frac{S}{n(n-1)}} = \pm\frac{2}{3}\frac{\epsilon'}{\sqrt{n}}$$

as according to the theory of errors of Gauss the probable error is about $^2/_3$ of the mean error.

The foregoing has only been a discussion of what influence the so-called accidental errors of observation have. No account has been taken of what influence systematic errors might have. This must be specially considered each time which, in many cases, is quite simple. If again the case of a simple weighing is used the systematic error is perfectly defined by the deviations of the weights from the correct value. If the reliability of the calibration of the individual weights is known the systematic error can be evaluated at once, or if the true values of the weights of the individual pieces have been determined by an official test, systematic errors are practically impossible outside of the guaranteed limit of error and at any rate they lie below the limit of the determination of error of the weights. If, though, a comparatively simple composite measurement is made, i.e. a determination of density, 2 systematic errors are possible. 1 due to errors in

*In the United States and Great Britain, the probable error is generally used in physical measurements, and if no specific statement is made a quantity representing a certain accuracy and preceded by a ± sign may be considered as a probable error when found in an English text.

the weight, the other due to the method used for determining the volume of the body, that is if the latter is carried out by a measurement of length, due to the errors of the measuring instruments or, in the case of liquids, due to errors in the contents of the containers and also to the influence of temperature at this content. In such cases one must proceed purely mathematically in order to determine how one must proceed and what accuracy can be attained.

Economy in scientific and industrial investigations requires that no quantity be determined more accurately than is absolutely necessary because it must be considered that a more accurate determination involves, in the majority of cases, considerably more work and time. We will not consider such cases where this is not the case. Below this will be illustrated by a number of examples.

The usual procedure is to represent the quantity to be measured mathematically by an equation in its relation to a series of other quantities. One then proceeds quite generally so that this equation is differentiated, that is partially for the several unknown quantities; the sum of these partial differentials then gives directly the errors to be expected of desired quantity. It may be pointed out that these partial differentials are always introduced into the calculation with the positive sign because one never knows in which direction an error has been actually made, and as naturally the most unfavorable case must be considered that is that the error usually occurs in such manner that the individual errors fall in the same direction. For instance, in a determination of density, the latter is defined by the quotient of mass and volume. If the mass is accidentally determined, a little too high the density would be too high. If, for the determination of volume, an error has been made by which the space becomes too large, the result for the density would be too small. Now of course, there exists the possibility that both the mass is found too great and the volume too small that is the case where the result would be falsified to the greatest extent, and this case must naturally be taken into account when determining the error.

The density of a gas, is to be determined by measuring the time of escape. The relation between density d and time of escape x is given by the formula

$$d = C\,x^2$$

where C is a constant of the apparatus. Then $\partial\, d = 2\,C\,x\,d\,x$,
that is the possible error is proportional to twice that possible in measuring the time of escape.

A density of a solid body is determined by weighing in air and water. Then

$$s = \frac{M}{M-m},$$

where M is the weight in air, m in water. Consequently,

$$\partial\, s = \frac{(M-m)\,d\,M - M\,d\,M}{(M-m)^2}, \qquad = -\frac{m\,d\,M}{(M-m)^2},$$

and correspondingly

$$\partial\, s = \frac{M\,d\,m}{(M-m)^2}.$$

The total error therefore in the most unfavorable case, which of course must be considered, would become

$$\Sigma\partial\, s = \frac{M\,d\,m + m\,d\,M}{(M-m)^2}.$$

Let us assume that it in general will be true, that both weighings can be made with equal accuracy ($dM = dm$) then

$$\Sigma\,\partial\, s = \frac{(M+m)\,d\,m}{(M-m)^2}.$$

Two Examples: $M = 21.502 \pm 0.002$ g $\quad m = 20.315 \pm 0.002$ g

$s = \text{approx.}\ \frac{21.5}{1.2} = 18\ \ \Sigma\,\partial\, s = \frac{41.8 \cdot 0.002}{1.44} = 29 \cdot 0.002 = \pm 0.058 = \text{approx. } 0.06,$

$M = 2.502 \pm 0.002$ g, $\quad m = 1.315 \pm 0.002$ g,

$s = \text{approx.}\ \frac{2.5}{1.2} = 2.1, \qquad \Sigma\,\partial\, s = \frac{3.8 \cdot 0.002}{1.44} = 2.7 \cdot 0.002 = +0.005.$

It will be seen from the above that, with the same accuracy of weighing, for 2 bodies of only 1 cc volume but of very different densities the latter are obtained with very different accuracy. In the first case 0.06, in the second 0.005. But at the same time it will be seen that the percent accuracy is approximately the same in both cases, namely $\left(\frac{0.06}{18} \times 100 = \frac{1}{3}\%,\ \frac{0.005}{2.1} \times 100 = \frac{1}{4}\%\right)$, a difference of a few tenths of a percent. If, therefore, the measuring accuracy is to be 0.1%, i.e.

$\frac{\Sigma\,\partial\, s}{s} 100 = 0.1, \quad \Sigma\,\partial\, s = 0.001\, s,$ therefore $d\,m = 0.001\, s \frac{(M-m)^2}{M+m}$, and

$s = \frac{M}{M-m}$, from which we have $d\,m = 0.001\, \frac{M(M-m)}{M+m}$,

in every case the required accuracy can be determined.

Finally, gravity is to be determined from pendulum measurements from the formula

$$t = \pi \sqrt{\frac{l}{g}}$$

(t the period of oscillation, l length of pendulum to be determined by measuring the length). From this follows

$$g = \frac{\pi^2 l}{t^2}, \quad \partial\, g = \frac{\pi^2}{t^2}\,\partial\, l, \quad \partial\, g = -\frac{2\,\pi^2 l}{t^3}\,\partial\, t, \quad \Sigma\,\partial\, g = \frac{\pi^2}{t^2}\left(\partial\, l + \frac{2\,l}{t}\right).$$

If we have a pendulum of approx. 1000 mm length which has period of oscillation of approx. 1 second, then an error in measuring the length of the pendulum of 1 mm gives an error in g of

$$\partial\, g = \frac{\pi^2}{t^2} 0.001 \text{ (in Meters!)} = \frac{9.9}{1} 0.001 = 0.0039 \text{ m/sec}^2$$

and an error of 0.01 seconds in determining the time

$$\partial\, g = \frac{2 \cdot 9.9 \cdot 1}{1} 0.01 = 0.19 \text{ m/sec}^2.$$

One obtains the remarkable result that accuracy in measuring the time is the most essential.

If a quantity is measured so that it depends on several individual quantities which is for instance the case for the determination of density above (weight and loss of weight) or gravitation (length of pendulum and

period of oscillation) the most unfavorable condition has always been assumed that both errors are wholly additive. It will be still more unfavorable, comparatively, in frequent cases where more individual errors still exist.

It is however quite obvious that in practice the case is somewhat different. Of course, the case assumed is possible but not probable, as it cannot be assumed that in all individual measurements the greatest possible errors have been committed, and that they all tend to falsify the result in the same direction. The theory of probability, on the contrary, teaches the following; a quantity u is to be defined by a function $u = f(x, y, z, \ldots)$ by measuring the variables $x, y, z \ldots$, and the error of u then depends on the errors possible with these individual measurements. According to what was said above it is

$$\partial u = \frac{\partial f}{\partial x} d x, \quad \partial u = \frac{\partial f}{\partial y} \partial y, \text{ etc., and } \quad \Sigma \partial u = \frac{\partial f}{\partial x} d x + \frac{\partial f}{\partial y} d y + \ldots$$

that is the greatest error possible in the result if all individuals are added without taking the sign into consideration, but not the error to be expected. The latter denoted as $d u$, is given by

$$d u^2 = \left(\frac{\partial f}{\partial x} \right)^2 d x^2 + \left(\frac{\partial f}{\partial y} \right)^2 d y^2 + \ldots$$

In other words the error to be expected is obtained by taking the square root of the sum of the squares of the individual errors.

We will turn back once more to the example mentioned above of the determination of density. In that case

$$\partial s = \frac{M \, d \, m}{(M-m)^2}, \qquad \partial s = \frac{m \, d \, M}{(M-m)^2}$$

and let us take the first numerical example with the slight change that we can carry out the more difficult weighing in water somewhat less accurately. This then gives

$$M = 21.502 \pm 0.002 \text{ g}, \qquad m = 20.315 \pm 0.005 \text{ g},$$

$$\partial s = \frac{21.5 \cdot 0.005}{1.2} = \pm 0.090, \qquad \partial s = \frac{20.3 \cdot 0.002}{1.2} = \pm 0.034.$$

The greatest possible error is, therefore, $\pm$ 0.124, but the error to be expected

$$\Sigma \partial s = \sqrt{0.090^2 + 0.034^2} = \sqrt{0.008100 + 0.001156}$$

$$= \sqrt{0.009256} = \pm 0.096.$$

This shows the importance of the accuracy of the weighing in water.

2. Scientific and Industrial Measurements and Instruments.

It may be of interest to discuss at this point, in a little more detail, the importance of the measuring instruments proper. Generally 2 types are distinguished, scientific and industrial instruments or, expressing it more commonly; good and bad ones. This is a distinction which might have had its justification formerly but is no longer true as by comparing scientific and industrial laboratories one can easily observe that the instruments used by both approach each other more and more, and that just the so-called industrial instruments find more and more application in scientific laboratories.

Perhaps the following distinction can be made; it is the aim of science when experimenting to define the physical and chemical properties of bodies and their relations numerically with the highest attainable accuracy, and likewise, the general laws should be checked with such accuracy as they permit and as the means at hand make possible. It has been determined by experience in innumerable cases that an increase in the accuracy of measurement by no means has, as it were, a sport-like importance, and that it is not at all irrelevant whether the accuracy of a physical constant can be increased by another decimal. Quite the contrary, each improvement in accuracy necessitates new test arrangements and compels the use of extensive auxiliary means and has thereby brought forth new knowledge because the whole field had to be worked on a much broader foundation. In other words, it can well be said that each increase of accuracy was an increase in scientific knowledge. With respect to chemists, one may mention in this connection the investigations initiated by Landolt[1] which had as their purpose checking the law of the conservation of mass in chemical reactions, or the many investigations connected with the discovery of rare elements.

Therefore the following statement might perhaps be made; For scientific investigations measuring instruments are used which meet the highest demands of accuracy, which can be checked in their service in all details, and which permit carefully testing and determining foreign influences on the result. For these instruments it will be of less importance to work quickly and simply than correctly and absolutely reliably, particularly so that all possible sources of error can be stated and taken into account, and that it can be determined in which manner they falsify the result. It does not matter, therefore that each application of such instruments requires a considerable amount of calculation. Also, the construction of the instruments will not be based so much on stability and care against rough treatment as it can be assumed from the beginning that only fully competent and experienced observers will use such instruments.

Of quite a different nature are the demands placed on so-called industrial instruments. On the one hand, it must be considered that industry nowadays more than ever, must operate economically, and this determines the basis for the construction of industrial instruments. Of course, they must also be accurate, but no more than absolutely necessary because each increase in accuracy means higher cost and time loss. Therefore, more attention will be given to the accuracy of an industrial instrument than to that of a scientific instrument. In addition its application should be as simple and convenient as possible. Inexperienced users should be able to use it efficiently without damage and without impairing its accuracy. With this consideration in view it must be built ruggedly in order to stand up under use by inexperienced observers and cheap labor, and finally, its indications must not be influenced by external conditions. If a scientific instrument is not compensated for temperature, it need not be in order to study the important influences of temperature on the constants, and even if particular stress is laid upon the fact that such influences can be studied in the finished instrument, in industrial instruments considerable value is placed on the elimination of the influence of temperature variations as much as possible or to build it entirely free of disturbances.

If it is especially emphasized that in the construction of industrial instruments questions of economy and therefore the question of price of the instru-

1 Landolt, Zeitschrift feur physikalische Chemie, Vol. 55, 1906, page 589: Ueber die Erhaltung der Masse, 19[illegible]

ment are determining factors, this will not mean that it is not the case for purely scientific instruments. Gradually also scientific research institutes are forced to consider economy in their work more than ever and to utilize the advantages of the industrial instruments. Besides, it is no longer true that science works more accurately than industry. If it is realized that in the manufacture of tools which is without doubt a purely industrial operation, accuracies in the measurement of lengths are demanded which only a few years ago were left entirely to scientific precision laboratories, then such a condition is well worth considering, and if one also considers that measurements with light interference were likewise considered as the highest degree of scientific work it must be pointed out that in the manufacture of tools one regularly uses this method in the shop, and in chemical operations regularly for the analysis of gases. It is natural that, in general, science will demand greater accuracy but with the closer cooperation of science and industry very frequently it occurs that science is compelled by industry to work more accurately than before in order to make it possible for industry to fulfill its tasks so that science must work more accurately than its own purposes would seem to make necessary. Such a case was realized in the case of length measurements of the manufacture of tools. The finest scientific measurements of lengths were in certain cases no longer sufficient for the purposes of the highest class of tools. There were methods known to satisfy such demands but they were too complicated in their application so that they could not be used. On the other hand, industry had to make such demands on science, and thanks to the cooperation, in short time they succeeded in developing measuring methods with light-wave lengths to such an extent that they became applicable for an industrial operation, and these methods may have given further impetus to the more perfect development of other apparatus, i. e. the apparatus for the gas analysis according to Lowe (see chapter on optical measurements.)

After what has been said it will hardly be possible to make a distinction between scientific and industrial instruments. Especially in chemistry the interrelation between science and industry has perhaps always been closer than in other fields so that great differences in these 2 types of instruments never existed.

3. Numerical Calculation of Test Results, Expediencies for Computing.

The importance of the numerical treatment of test results has been pointed out several times before, and emphasis made that in scientific work numerical problems are not unimportant and a measuring method can not be dismissed because it involves more computation. In general however, methods which avoid computations as much as possible to reduce it to a minimum will be given preference. After all it has been found that even in simple and quite elementary computations errors which are practically unavoidable, creep in, even with the greatest care, and that it is absolutely advantageous for this reason for everyone to also have some practice in computing.

If possible all computations should, in more important work, be checked over numerically by a second observer or, what is still more advisable to note down all observations in duplicate, using carbon paper and to have them computed by 2 men independently of each other, if possible by different methods and with different means. Then if these double results agree a fair assurance against errors in computing is obtained.

The means for calculating at one's disposal are manifold. First, the purely mechanical will be briefly discussed.

They are mainly the slide rule and the calculating machine. The principle of the slide rule is quite simple; it aims to replace the multiplication of 2 numbers by an addition. It has 2 similar scales movable with respect to each other which show divisions from 1 to 10 and are subdivided in such manner that at each place of the division the common logarithm of the number is engraved instead of the number proper. Since the logarithm of 2 is 0.30103, there is put at the place which is 0.30103 of the total length of the scale the number 2, and at the place corresponding to the length of 0.4771 the number 3; in this way, the entire division of the slide rule is carried out. If one, therefore, desires to multiply 2 numbers one simply places the index point of the movable scale over the first number on the rule, then the product of the 2 numbers is read directly on the cursor whose mark is placed above the second number on the slide. There are a large number of constructions of different slide rules which, of course, can not only solve this simple problem of multiplication but in exactly similar manner problems of divisions, roots, powers, and complex problems.

The following forms of the slide rule are in use: The small rule with simple scales about 12½ cm in length, especially used for pocket slide rules made of card-board or wood, quite useful, but only for calculations of moderate accuracy due to its size. The standard 25 cm slide rule also made of card-board or wood, is much better. The first is reasonably accurate but fragile, the second also considered a pocket slide rule which has a long scale of 25 cm and two adjoining shorter ones of 12½ cm each. This is the real standard slide rule which is sufficient for almost all purposes. Finally there exists a third form of the same type but of double the length with correspondingly increased accuracy but, due to its length, is only used in special cases. In all these forms auxiliary divisions are provided, for instance, for third powers or cube roots respectively, logarithms and angular functions. There is also still another form often in use, not in a straight line but circular about the size of a watch, 10 cm diameter, which practically gives the same service as the standard 25 cm slide rule, but in a certain respect is somewhat superior to the latter as regards convenience; but on the other hand is perhaps not quite so convenient for reading as the instrument must be continually turned around. The construction of good slide rules is usually of such good quality that the divisions are correct within a few hundredths of a millimeter so that errors due to defective division is hardly to be expected. However when buying it is advisable to check this, which can easily be done by making a few calculations.

It is self-evident that in using a slide rule, the mathematical problem of the multiplication of 2 given numbers which can be solved with absolute accuracy by means of elementary computing methods, is reduced to a measurement and is therefore, subject, while not to errors of measurement, to errors of setting and reading. To this must be added eventual errors caused by defective divisions. If these possible errors are disregarded and it is assumed that each adjustment is made correctly to 0.1 mm which can be easily done with a little practice then there is a comparatively simple mathematical consideration, which will not be given here, that for a simple multiplication or division an average error of approximately 0.3% can be expected if a short slide rule is used or the short scale on the standard slide rule. If the long scales of 25 cm are used a mean error in the usual calculations of 0.15% is obtained, which means an error which in general can be considered as a very moderate and almost always admissable in the usual chemical computations.

The use of the slide rule for solving the most varied problems is quite simple and can be acquired quickly. Its profitable application requires the knowledge of a few tricks. It is practical to acquire a certain skill in seeing immediately what order the result of a problem should be as the slide rule operates logarithmically by omitting the characteristic. One obtains a result for which the position of the point must be found from other considerations. There are instructions as to how this position can be determined by the slide rule itself but that is fairly tedious. On the other hand it is generally never difficult to know from the beginning whether in an analysis the percentage of a substance is 0.35, or 3.5 or 35.

The second important, purely mechanical computing device is the calculating machine which in contrast to the slide rule, operates with absolute accuracy if all figures are always used. If, in the slide rule, 2 numbers of 3 figures each must be multiplied the result will be read again as a number of 3 figures. The calculating machine multiplies such figures absolutely correctly, and as already mentioned before, that is practically never necessary in physico-chemical work.

There are 3 fundamental types of constructions of calculating machines which can be considered all of about equal value for laboratory purposes. The first type operates with so-called stagger-rolls. The principal construction element of this machine is a series of cylinders carrying on their surface, pieces of different length parallel to their axes and equally distributed around the circumference, 10 in number, all beginning at the lower face and gradually going up to the upper face. The sections of the cylinder therefore represent at each place tooth wheels in which a few teeth are omitted, the lower face is a wheel with 10 teeth, at 0.1 of the cylinder length one tooth is missing, in the center 5 teeth are missing, and the last section has no teeth at all. By setting a number in the gear of the machine and turning a handle these staggered cylinders are turned by different amounts when operating this machine, and thereby the calculation is made. With this machine it is necessary to turn the handle the number of times corresponding to the one number with which one wants to calculate that is, if one number is set in the machine and to be multiplied by 27, then the handle has to be turned $2+7=9$ times, or according to another method, instead of multiplying by 27, by $30-3$, turned $3+3=6$ times. Naturally, there exists with quite a few possibilities to simplify the calculations considerably. This sort of machine is represented by machines of the *Tim* or *Spitz* type.

The second type of calculating machines has as the principal element gears, which have different numbers of teeth. Each of these gears has 10 teeth of which a definite number can be shifted out of their circumference according to the setting of the number in the gear, and then the calculation is made in a similar manner to that described above. These machines have the advantage that they permit turning the handle forward and backward and in this way to conveniently go over from multiplication to division. These machines are known in the form of the *Brunswick* or *Triumphator* machine. Finally, the third type, represented by the *Mercedes-Euclid* machine works in quite a different manner as here the calculation is carried out by swinging levers being changed in their lengths and pivots by the setting of the numbers. This type of machine has the advantage that the number of turns of the handle for the calculation is reduced to a minimum that it is even possible to operate these machines with an electric motor so that the whole calculation except the setting of the figures can be made wholly automatic by operating a single switch, an arrangement which is,

of course, extremely convenient, but consequently expensive. Which of the 3 types is to be selected is more or less a matter of taste, and especially a matter of cost in which connection it may be said that most firms build their machines with different numbers of figures and with more or less convenient useful incidental devices.

A further expedient which can be discussed here only very briefly, and which has become of considerable importance only during recent years is the process of nomography. In brief, the principle of this method can be described as follows: 2 mathematical functions are represented by straight lines or curves with divisions which are drawn on a sheet of drawing paper bearing a definite relation with respect to each other. Correspondingly a third function can be drawn on a straight line or curve also properly located with respect to the 2 others, and as soon as 2 points of 2 of these functions are given for example by some observed point, these 2 points are connected in the drawing by a straight line; the corresponding value can then be read directly at the intersection of the straight line with the third scale of the function. The whole procedure is so to speak a graphical solution of a problem of more difficult character, especially in such cases where the same problem is continually repeated in which however the actual drawing work has been done before hand and can be considered as given. Only in recent years has much been published in the literature on the application of nomograms. It is self-evident that in many cases no very great accuracy can be expected, for average accuracy, as it is generally required, this method offers an extraordinarily simple means for calculation.

Besides these purely mechanical means for calculating a series of others, in a certain respect also mechanical means must not remain unmentioned. These are the so-called calculating tables, which while available in most different forms, are in principle not much more than enlarged multiplication tables, as for instance those of Zimmermann or Crelle are nothing, but a collection of all products of numbers from 1 to 1000 respectively 1 to 10,000 with numbers of 1 to 100 absolutely correct. By suitable arrangement and proper application of these tables of products the most complex multiplication and division problems can be greatly simplified and reduced to comparatively simple numerical calculations.

Besides these general numerical tables, which generally are supplemented by special additional tables may also be mentioned, the tables in many handbooks which contain the squares and cubes of all numbers from 1 to 1000, square and cubic roots and reciprocials etc., and finally the well known logarithm table. It must be mentioned that for the chemist except in special cases, a table of 4 places will generally be sufficient, 5 places will be used only in important cases for greater accuracy. In the former we have without doubt the advantage that all logarithms can be put on 2 pages. Similar to the slide rule as mentioned before it can be stated that a table of 4 places provided care is taken in interpolation, gives a working accuracy of about 0.05%, that is considerably more than the slide rule.

4. Correction Calculations

It will be important for further numerical calculations, to discuss some more peculiarities, the essential purpose of which is to facilitate computing work. The importance of modifying the basic mathematical formulas in such way that they are as convenient as possible for the numerical calculation was pointed out. Also in some other manner a modification is practical and even useful, namely so that one need deal only with a few large numbers

while the greater part of the remainder only has the form of corrective quantities with very moderate requirements of accuracy. In discussing the difference between scientific and industrial measuring instruments it has been pointed out that the former are of quite a different kind in so far as corrections are concerned so that corrective calculations and corresponding tests become the principal feature for them. In industrial instruments these features will be more or less relegated to the background. Unfortunately, it must be taken for granted that no instrument is perfect. Especially, it is not possible to make divisions with absolute accuracy, just as sets of weights can not be subdivided with absolute accuracy in themselves. It would also be useless when making all such apparatus to try to obtain the utmost accuracy as it can not be perfectly achieved and also would be lost in course of time. As a matter of course weighing sets, used very much, must become lighter gradually, simply by wear, and likewise, if the knife edges of a balance suffer through use the equality of beams of the balance is questionable. If, therefore, greater accuracy is necessary, correction measurements must be made in each case. Industrial instruments, as said before, are so advantageous for many purposes for the reason that by foregoing the highest accuracy they endeavor to make corrections unnecessary as much as possible.

Further, it may be pointed out that certain improvements of measured quantities are unavoidable as they influence those quantities due to exterior conditions. In determinations of density of liquids it is necessary to measure the temperature with great care as the temperature has a considerable influence on the density. It is of course, practically impossible to work exactly at a certain standard temperature, the tests can be carried out only in the proximity of the latter and the results of the tests must be converted to standard temperature. That is the most necessary corrective calculation for determinations of density. A second known correction due to temperature, is the expansion of the containers in which the liquid is kept, for example for pyknometers. Necessary correction for the buoyancy in weighing will be discussed more fully later.

When making measurements therefore, one must have a clear idea from the beginning which corrections must be considered, and which can be ignored. One must know how large the individual corrections are, and what influence they will have on the result. Then only is it possible to judge which are of no importance in the case in question, and how, in a given case, the measurement must be arranged to eliminate a few of the corrections or to be able to determine them with sufficient accuracy. In numerical calculations it can hardly be carried out without a thorough reasoning which considers the quantity and reliability of the corrections. On the contrary, the mathematical formula which is to be used will generally be split up in such manner that one part gives the principal results which then is improved by the corrections. It must almost be made a rule that corrective quantities should be calculated mentally as much as possible or at least by the slide rule, and for that it is possible to use simple expediencies. The majority of corrections are small figures compared with the principal result, and this must be utilized for the calculation, and also that many can be represented in a form to give a number close to 1, therefore be represented by a number of the form $1+\alpha$. In this way the correction is reduced, so to speak, to a small number, namely, to a number which is added to or subtracted from 1. For the calculation of such numbers which either are small or lie in the neighborhood of 1, there exists quite a number of

rules and formulae which may be given in the following without proof. It may be briefly mentioned that all these formulae have been derived by developing the original form into a series of which the first number only is of importance numerically while the second and likewise all the following are so different in order from the preceding ones that they need no longer be considered numerically. A few examples may illustrate the application of these formulae.

The numbers designated by α, β, γ, should be so small in comparison with 1 that their square and higher powers can be entirely neglected, also the products of $\alpha\beta$ and similar. The following formulae hold:

$$(1+\alpha)^m = 1+m\,\alpha, \qquad (1-\alpha)^m = 1-m\,\alpha$$

$$(1+\alpha)^2 = 1+2\,\alpha, \qquad (1-\alpha)^2 = 1-2\,\alpha$$

$$\sqrt{1+\alpha} = 1+\frac{\alpha}{2}, \qquad \sqrt{1-\alpha} = 1-\frac{\alpha}{2}$$

$$\frac{1}{1+\alpha} = 1-\alpha, \qquad \frac{1}{1-\alpha} = 1+\alpha$$

$$\frac{1}{(1+\alpha)^m} = 1-m\,\alpha, \qquad \frac{1}{(1-\alpha)^m} = 1+m\,\alpha$$

$$\frac{1}{(1+\alpha)^2} = 1-2\,\alpha, \qquad \frac{1}{(1-\alpha)^2} = 1+2\,\alpha$$

$$\frac{1}{\sqrt{1+\alpha}} = 1-\frac{\alpha}{2}, \qquad \frac{1}{\sqrt{1-\alpha}} = 1+\frac{\alpha}{2}$$

$$\sqrt[3]{1+\alpha} = 1+\frac{1}{3}\alpha, \qquad \frac{1}{\sqrt[3]{1+\alpha}} = 1-\frac{1}{3}\alpha$$

$$(1+\alpha)(1+\beta)\ldots = 1+\alpha+\beta\ldots \qquad \frac{(1+\alpha)(1+\beta)\ldots}{(1+\gamma)(1+\delta)\ldots} = 1+\alpha+\beta\ldots-\gamma-\delta\ldots$$

Example:

$$\sqrt{\frac{1.00036}{1.00257}} = \frac{1.00018}{1.00128} = 1.00018 - 1.00128 = 1 - 0.00110 = 0.99890,$$

$$\frac{1}{0.9934^3} = \frac{1}{(1-0.0066)^3} = 1+3\cdot 0.0066 = 1.0198,$$

$$\frac{1.00034567}{0.99992765} = \frac{1+0.00034567}{1-0.00007235} = 1+0.00034567+0.00007235 = 1.000418\,2$$

If a and b are any 2 numbers not very different from each other then

$$\sqrt{a\,b} = \frac{a+b}{2}.$$

Calculating with small angles:

$\sin\alpha = \alpha$, $\cos\alpha = 1$, Angle 1 in Radians 57,3°,

$\sin 1° = \sin 60' = 0{,}01745$, $\tan\alpha = \alpha = \sin\alpha$, $\cot\alpha = 1 = \cos\alpha$,

$\sin 1' = \sin 60'' = 0{,}002908$, $\sin\alpha = \alpha \sin 1°$,

Example:

$$\sin 53' = \frac{53}{57.3\cdot 60} = 0.0154, \qquad \sin 53' = 53 \sin 1' = 53 \text{ x } 0.002908 = 0.0154$$

The angles, of course, must be put in here as radians. In spite of the apparent paradox in the formulae no such exists in reality.

NEW INSTRUMENTS

Recently Developed by Instrument Manufacturers

Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional information.

A New Indicating Frequency Meter

*Paul MacGahan**

ALTHOUGH several principles of operation govern the classes of frequency meters, by far the most important one for meters of the indicating class is the ratio indication type. This has been made with movements operating on various principles such as the induction type, or the moving iron electromagnetic type, or the three-coil dynanometer type. Generally speaking, all of these instruments work through the development of opposing electrical forces acting upon the movement and so arranged that the pointer will move across the scale to the point at which the 2 opposing torques are exactly balanced. Thus these instruments differ from ordinary voltmeters or ammeters in that the electrical forces do not act against mechanical control forces such as springs. A spring controlled frequency meter would be influenced by variations in applied voltage, which changes the electrical torque without influencing the mechanical control torque.

It is a difficult problem of design to produce a frequency measuring instrument whose indications will be independent not only of the applied voltage, but also independent of temperature variation, wave form variations and other disturbing influences.

The earlier forms of frequency meters operating on the ratio principle used a divided electrical circuit, 1 branch being wound as non-inductively as possible. As the frequency varied, the ratio between the currents in the divided circuit varied, and this allowed the instrument to be calibrated in terms of frequency.

A somewhat greater sensibility was obtained by using a condensive circuit instead of a non-inductive circuit in 1 branch and balancing it against the inductive branch. However, it was found impractical in such instruments to avoid temperature errors due to variations in the condensers. The simple form of the divided circuit idea of which probably the first example on a practical basis was the Westinghouse type F disc operated induction meter, resulted in the first practical direct indicating meter. The scale range of from 25% below to 25% above normal frequency was about the limit for such instruments making most of the scale range practically useless on modern systems, the frequency of which is maintained within close limits. The necessity for accurate indications within a narrow range of frequency only, led to the development of resonant circuits for the ratio type instruments, preferably using the dynanometer form of construction.

The Type SY frequency meter about to be described is the latest development along this line and the design permits the production of instruments having a scale range of $\pm$ 2 cycles for 60 cycle work, with operating torques at least equal to those used in corresponding voltmeters, and a remarkable freedom from temperature or voltage error effects. At the same time, the

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power consumption of the instrument has been so reduced that the instrument can be operated from a section of a condenser bushing thus avoiding the use of expensive transformers when applied to high voltage systems.

These instruments differ from the usual resonance type of ratio instruments in that a single resonant circuit of the parallel type is employed, which results in a very low volt-ampere burden. Fig. 2 shows the internal connections. The circuit design is such that the change of resistance of the reactors and coils due to temperature variations produces no effect whatever. The indication depends only on the values of inductive and capacitative reactance. Thus the temperature effect is so small that it can hardly be measured. The use of a special type of condenser is partly responsible for this performance.

Fig. 1.—Resonance Type Frequency Meter. (above)

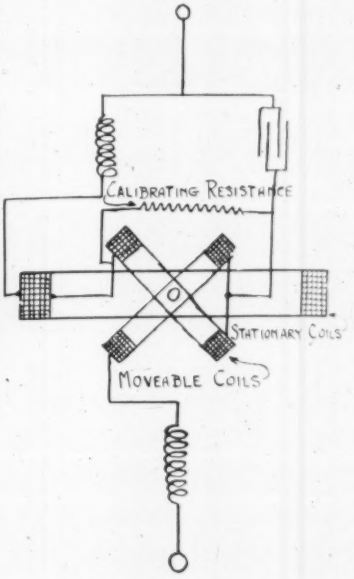


Fig. 2. Type SY Meter, internal connections. (at right)

The ranges obtainable are from 54 to 66 cycles or from 58 to 62 cycles for use on 60 cycle systems. The narrow range scales are supplied for use on inter-connected systems and applied principally to power or load dispatching.

Since such an instrument is responsive to changes of .01 cycles, frequency changes due to the load can be readily observed. The instrument is more accurate than the usual means available for calibrating. It therefore follows that where several instruments are required for load dispatching purposes at different points of a system, it is preferable to have all these instruments calibrated together, so as to eliminate the effects of individual observation errors in the original calibration.

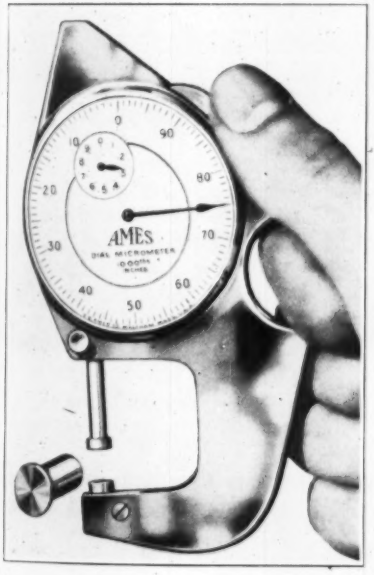
In order to calibrate frequency meters as accurately as the scales themselves will indicate, requires very elaborate apparatus including standard tuning forks kept at constant temperature, together with photo-electric cells and amplifiers.

This frequency meter consists of a stationary field coil within which 2 moving coils mounted on the same shaft at right angles are free to turn.

Therefore, mechanically, the instrument is similar to previous types of dynanometer frequency meters. The position which the 2 coils take up, depends on the relative electrical forces produced by the currents in the winding. The ratio of the forces determines the position of the pointer. The electrical forces are proportional to the product of the currents in the fixed and moving coil and cosine of the angle between them, or what amounts to the same thing, the product of the fixed coil current by the in-phase component of the moving coil current. We will take as a reference, the current in the 1 moving coil and reactor as this passes through the stationary coils of the meter. The voltage drop across the coils and reactor is applied to the condenser and the sum of the 2 currents flowing through the other moving coil, as shown in the diagram. This voltage drop has 2 components, 1 in phase and 1 out of phase 90°. These components when applied to the condenser which has a very low power factor produce currents 90 and 180° out of phase. These currents combined with the original current flow through the other moving coil and produce torque proportional to the differences or the original and the 180° imphase currents. The 90° component producing no torque of course. At the normal frequency, the sum of the in-phase components is zero and is positive or negative depending upon whether the frequency is low or high. Since the effects of the coil resistance only alters the 90° component, changes in resistance due to temperature changes produce no effects. Changes in the resistance of the other moving coil produce no effects, but a reduction in the voltage across the resonant circuit, and this has no effect as both coils have their forces equally altered, but the ratio between them remains the same.

New Dial Micrometer

(B. C. Ames Co.)



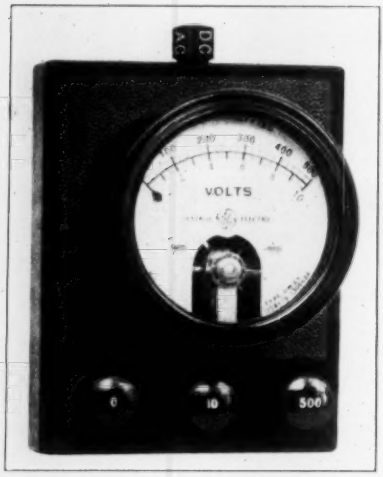
THIS gage can be used for measuring and testing round, flat or odd shaped machines parts, automotive parts, tools, round or flat stock, rubber, textiles, sheet metal, ware, paper, cardboard, etc.

It is of strong, rugged construction yet extremely sensitive. Each thousandth of an inch is amplified to an easily readable size.

A quick acting spring spindle is lifted by a simple upward movement of the thumb. It closes itself into position on the work to be measured and the reading is indicated instantly on the face of the dial. The reading can be locked in position by means of a simple snap and the instrument used for testing as a snap gage for 1 inch capacity.

New Portable Voltmeter

THE General Electric Company has introduced a new portable high resistance voltmeter, Type DW-2X, for both alternating and direct current use. It can be used for general purpose testing and is particularly useful for radio applications, where it is essential that an inappreciable amount of current be drawn from the line. The instrument is supplied double range, 10/500 volts, with a resistance of 750 ohms per volt. The instrument is similar to the Type DW-1X, already described, except that it has a rectangular sub-base, $2\frac{3}{4}$ by $3\frac{3}{4}$ inches. A convenient knob projects through the top of the sub-base, permitting the instrument to be adjusted to read either alternating or direct current. Insulated binding posts are provided on the sub-base for changing connections.

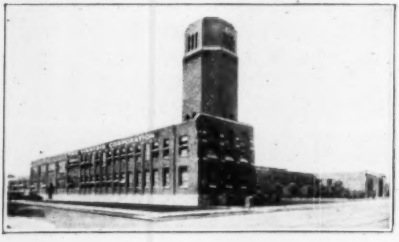


Lancaster & Allwine announce the association with their firm of Royal R. Rommel of the District of Columbia Bar under the firm name of Lancaster, Allwine & Rommel.

Mr. Rommel has had extensive experience in engineering and legal fields of endeavor and has been practicing before the patent office and in the Federal Courts of the United States for many years.

THE Mercoid Corporation, well known manufacturers of controls, have acquired a large modern plant, consisting of 90,000 sq. ft. of floor space to meet their growing needs.

They will be in their new location at 4201 Belmont Ave., Chicago, by April and visitors to the Seventh Annual Exposition and Convention of the American Oil Burner Association held at Hotel Stevens in their city, during the week of April 7th to 12, 1930 are invited to inspect their new plant.

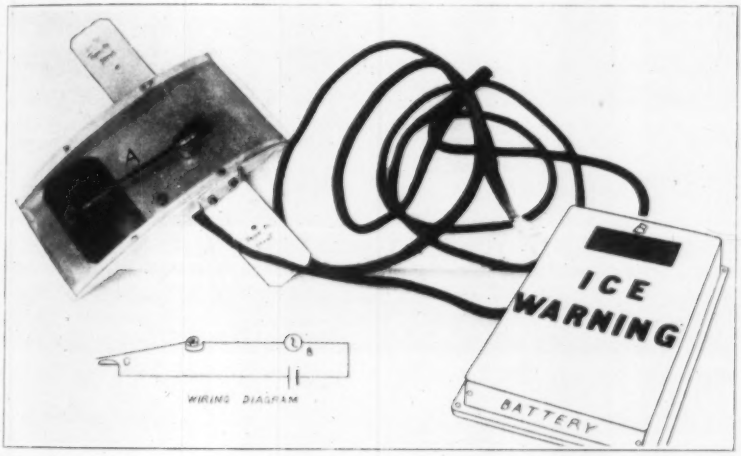


Effective February 10th the Detroit District Sales Office of Cutler-Hammer, Inc., will be located at 2755 East Grand Boulevard, Detroit, Michigan. The new location includes warehouse facilities where stocks of C-H products will be carried for immediate delivery.

An Ice Warning Thermometer*

H. B. Henrickson

A DEVICE which may find application as an indicator of the temperature range in which ice may form on an aircraft is shown in the illustration. It is essentially a temperature actuated switch which controls a red light on the instrument board of the airplane. The thermal switch A is located on the strut or otherwise exposed in the free air stream, while the indicator B is installed in a convenient place in the cockpit. The light, behind the red window B, appears only at temperatures from —4°C to 0°C, which, according to National Advisory Committee for Aeronautics tests described in Technical Note No. 293 has been shown to be the critical ice-forming temperature range. It warns the pilot with a minimum of mental effort on his part, the moment that his ship has entered a flying level at the temperature of which the clear, dangerous type of ice may form. For ease in installation on the ship, the instrument is made up in a unit with its own battery, using pocket flashlight cells of standard size. These are located in the small box B which contains the red warning lamp. The contact points C are made of coin silver. The lower contact, attached to an insulating sheeting of bakelite, is made crescent-shaped so that the switch arm can easily ride over it without jamming as the temperature increases or decreases.



The time lag of this instrument is somewhat greater than that of the Minimum Temperature Recorder, shown on page 323 of the September 1929 issue of "Instruments," because of the necessity for enclosing the coil and contacts for protection from the effects of the weather. This naturally prevents good ventilation of the coil, with the result that the time lag is increased somewhat. On the other hand the rather thin aluminum base of the instrument, to which the bimetal coil is securely attached, serves as a good radiator, so that the resulting time lag of the entire instrument may not be considered excessive.

*Publication Approved by the Director of the Bureau of Standards of the U. S. Department of Commerce

Tests in the laboratory on a standard vibration board, and in an automobile over rough roads when the temperature was 0°C both showed that the bimetal coil with its attached switch-arm is sufficiently stiff to function properly when subjected to severe vibrations. Flight tests, made through the courtesy of Roger Scott, operations manager of Hoover Field, Washington, D. C., during last December showed that the instrument will function satisfactorily in airplanes.

Bilby Steel Tower for Triangulation*

(U. S. Coast & Geodetic Survey)

THE extraordinary accuracy of the first-order triangulation work of the Coast Survey is primarily due to precise instruments and economical and efficient methods conceived by the many engineers on its staff during the 113 years of its existence. With the adoption of an excellent signal lamp, the vastly improved theodolite, and the use of invar tape, it remained for Jasper S. Bilby, of Osgood, Indiana, for many years in charge of its signal building operations, to design a steel tower as a substitute for the costly wooden structures built. They are inexpensive, compared with wood, and can be promptly reared to varying heights and as readily dismantled for transportation by truck to another station for set-up.

Since a geodetic survey is one which gives consideration to the curvature of the earth, it is not unusual for ridges, trees, and buildings to obstruct the line of vision between contiguous triangulation stations, at times 25 miles apart. Towers are therefore utilized to elevate the signal light at the one station on which observations are made, and the theodilite, with which the observations are made, at another station.

These steel towers consist of two mutually independent tripods, so that no movement of the observer operating on his platform on the outer tripod tower can jar the theodolite at the apex of the inner tripod and thus affect its accuracy.

The signal lamp on which observations are made is supported at the top of the outer tripod, 10 feet above the theodolite.

The Bilby tower was first used in Minnesota several years ago and has been in almost constant use since that time on hydrographic work in Florida and on arcs of triangulation in Ohio, Pennsylvania, and New York. During the 1929 season it has also been used on the arc of triangulation between Cairo, Ill., and New Orleans, La., which the Coast Survey is executing at the instance of the Mississippi River Commission.

The first steel towers were only 75 feet to the top of the inner tripod, but were later increased to 103 feet by additional lower sections. The tall trees found in the lower Mississippi Valley this season, however, made it necessary to further increase the inner tripod to 129 feet, with supplemental 10-foot extensions available for emergencies. The outer tripod is always 10 feet higher than the inner structure.

*Special Publication No. 158, U. S. Coast & Geodetic Survey.
Copies are for sale at 15 cents by the Superintendent of Documents, Government Printing Office, Washington, D. C.

Many Ingenious Devices Use the Photo-Electric Cell

(Westinghouse Electric & Mfg. Co.)

LONG merely an exhibition novelty, the photo-electric cell is now the brain of many commercial devices. A very practical use is in promoting efficient combustion in boiler plants. The appearance of the flue gases passing up the stack is a very fair gage of the fireman's skill, and of the sufficiency of the air supply.

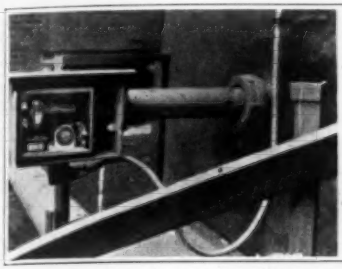
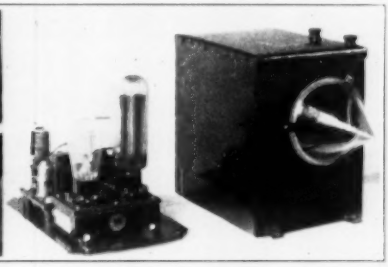


Photo-Electric Cell which analyzes flue gases.



The Photo-Electric Cell Unit used for Daylight Control of Lights.

From a lamp on one side, a ray of light passes right through the stack and its flue gases to a photo-electric cell on the other side. The opacity of the gases is measured by the amount of light that gets through, and is indicated on a meter in the fireroom. Several installations have made it clear that knowledge of what the chimney is doing tends to intelligent firing, and actually results in a nearly clear stack.

A most useful application of the light relay's visual ability is the control of factory lighting. As daylight waxes and wanes, shop lights are turned on and off by the daylight itself. The worker's speed and the quality of product depends largely on adequate lighting. With this control, which responds more accurately to the varying need for artificial light than can human judgment, larger lamps, burning only when needed, can be used to give better factory illumination without increasing the monthly power bill. In long aisles, light control units at intervals can turn on and off the banks of lamps in their particular region. In one installation, two adjacent areas, each of 8000 watts were controlled, one by the daylight relay, and the other by the whims of the workers. With apparently adequate light in both, the hand-controlled section used two and one-third times as much power as the area under daylight control during the three month test.

The photo-electric cell is the vital part of many other ingenious devices, a few of which follow: sheets of paper flying past the cell are accurately counted at the rate of 60 sheets a second; suspicious smoke from electric machinery turns on fire smothering gas before material damage occurs; defective pieces are sorted from a moving production line by their own defects, and doors of automatic elevators hold themselves open as long as passengers are getting on or off.

As the optic nerve for modern talking motion pictures the photo electric cell is a basic necessity to one of the most widely known and highly capitalized of modern development. Industry, in general, is just awakening to

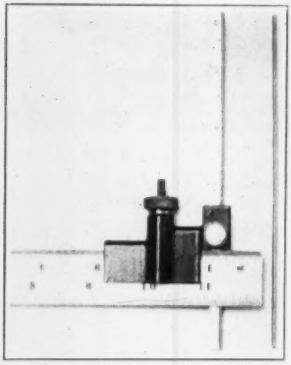
the possibilities of the photo-electric cell. The field of its use in the next few years is a question not so much of the device itself, as of the imagination shown by industry in perceiving uses for it.

Kindred devices also have ingenious application possibilities. For example, the grid glow tube is an excellent safety device for domestic oil burning furnaces. Serious explosions may occur by belated ignition of the burner after the oil is turned on, or if the flame goes out unexpectedly. Instead of relying on heat to tell when the flame is burning, the grid glow tube utilizes the electric conduction of the flame, i.e., no flame, no control current. As compared to the dangerous 5 to 90 second delay, required by former thermal devices the grid glow tube responds instantly.

New Measuring Instruments

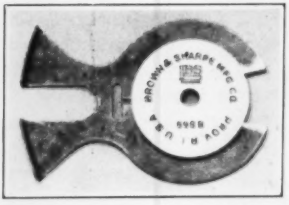
(*Brown & Sharpe Co.*)

No. 468 Depth Gage Attachment. This attachment measures directly from the lower edge of the blade of square or set and is easily read. It is a particularly useful tool for measuring the depth of wide recesses.



English measure Attachment has a range of 0″ to 4½″ with 6″ blade graduated in 32nds and 64ths, or 64ths and 100ths. Blade with 32nds and 64ths graduations is furnished unless otherwise specified. Metric measure Attachment has a range from 0 to 114 mm with 15 cm blade graduated in mm and ½ mm. A rod, 5/64″ in diamter, is furnished for use in small holes. No. 468 may be used on 9″-12″-18″ and 24″ Brown & Sharpe Combination Squares and Sets. It cannot be used on Combination Squares and Sets with heavy blades.

Wire Gage Selectors Nos. 698A & 698B. Two Wire Gage Selectors, Nos. 698A and 698B, simplify the gaging of wire.



Wire Selector 698B

These selectors cover up the slots in the wire gauge adjacent to the one being used, so that the one slot in the wire gage for any particular size is made accessible for fast and easy gaging. These Wire Gage Selectors simplify the gaging of a large number of pieces of wire.

The selectors are easily and quickly attached to wire gages. The spring fingers of the selector arm snap around the stud on the disk, holding the selector in place on the wire gage. If desired, the selector is easily removed. There are no screws or nuts to become lost.

Selector No. 698A is for use on Brown & Sharpe Wire Gages Nos. 688 (5 to 36) and 690 (6 to 36); and Selector Nos. 698B is for use on Brown & Sharpe Wire Gages Nos. 688 (0 to 36), 690 (1 to 36), 692, and 694.

A Means of Measuring Ultra-Violet Rays

Westinghouse Electric & Mfg. Co.

ULTRA-VIOLET rays, formerly were but a name strayed from the physics laboratory, even to persons of some education. Within a few years they have achieved popularity. They are reputed to increase the body's resistance to colds and infections, to pneumonia and grip, to be a cure for the rickets of infants and the baldness of age. Besides these claims, it is certain they produce sun tan, the current vogue of beauty. A considerable traffic has appeared in devices to produce ultra-violet rays artificially, and in glass, or its substitutes, which will allow passage to the natural supply from the sun.

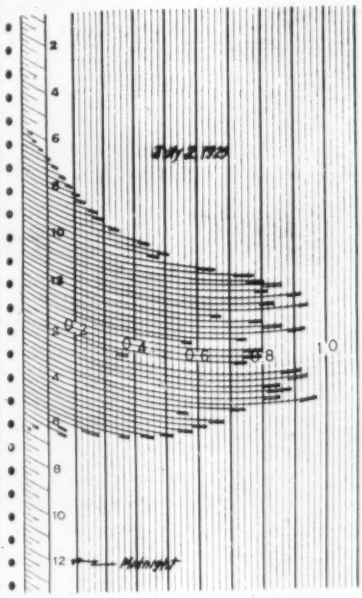


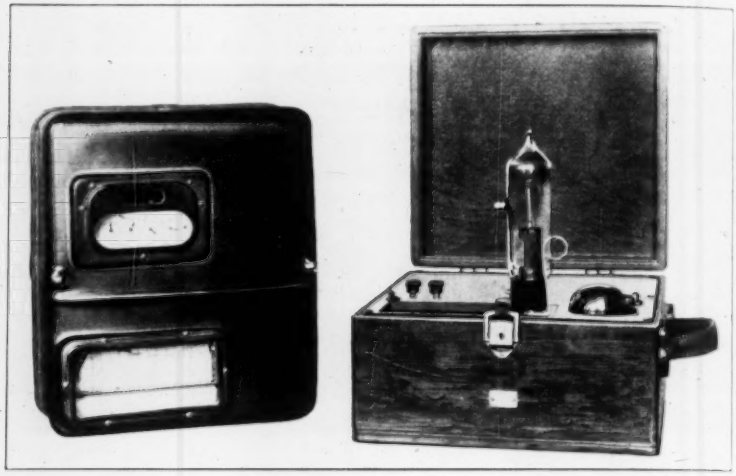
Chart of a Graphic Ultra-Violet Ray Meter

It is remarkable that there has been, until this year, no convenient means for measuring this ultra-violet radiation. Such a portable indicator, or meter, is now available—a case 9 by 11 by 12 inches, operating from dry cells within it. Whenever the photo-electric cell, which is the eye of the set, has received a definite quantity of radiation, there is a slight snapping sound, which is rung up on a counter. Thus the intensity of the radiation can be judged by the frequency of the sounds and the total amount received, by their number.

The photo-electric cell, developed by Dr. H. C. Rentschler, is made with an active material sensitive only to that part of the spectrum whose wave lengths are believed to have affects on vitality, i. e., from 3100 to 2900 A. U., that is, of wave lengths 0.000 31 to 0.000 29 millimeters.

This indicator measures the quantity or integrates the amount of light ove a given period of time. The rays falling on the cell allow a small amount of current to pass through it. This current is proportional to the intensity of the rays. The current through the cell charges a condenser and when the condenser is fully charged it trips a counter. After this impulse operates the counter the condenser is again charged and the operation repeated. Each impulse measures a definite quantity regardless of the rate of intensity. Where the ultra-violet ray source is known to be constant the intensity can be determined or compared to another source by counting the impulses per minute. This unit or impulse at the present time has no name and the value taken is arbitrary.

A graphic meter can be supplied that records the impulses from the ultra-violet indicator. In this case a relay is furnished with the indicator instead of a counter, and each impulse notches up the pen of the recorder. At five or fifteen minute intervals the pen is automatically reset to zero. This chart then gives a continuous graphic chart of the impulses that occur in periods of five or fifteen minute intervals. The graphic meter operates from a light circuit of 110 volts, and will give a continuous record for 30 days. In the study of sunlight or of smoke regulation the graphic recorder will be necessary.



The Photocell in this Ultra-Violet Ray Recorder Responds only to Wavelengths from 3100-2900 A. U.

While medical science is somewhat cautious about giving an opinion as to the effects of ultra-violet radiation, the known results appear to hint at extraordinary possibilities, affecting human well being in many aspects. Whatever these possibilities may develop, we are at least now armed with the primary tool—a means of measuring the force we deal with.

The Foxboro Company announce the removal of their Los Angeles Office to 2307 East Eighth Street. This office has been reorganized for the purpose of assuring Southern California the same Foxboro engineering service enjoyed by other sections of the country. Dudley M. Hill will be in charge, assisted by an entirely new staff of trained and experienced engineers.

The P. H. & F. M. Roots Company, manufacturers of Rotary Positive Blowers, Pumps and Meters has merged with other interests and is now under the control of the Stacey Engineering Company. The new organization includes the P. H. & F. M. Roots Company and The Connersville Blower Company, both of Connersville, Ind., The Wilbraham-Green Blower Company of Pottstown, Pa., and the Stacey Brothers Gas Construction Company of Cincinnati, Ohio. All companies involved in the merger will maintain their separate identities and organizations, and will continue to operate separately until the final plans of the merger can be consummated.

Eötvös Torsion Balance

(George Steiner, Incorporated)

THE instrument, which is the invention of the late Baron Roland Eötvös, is widely used in search for oil and mineral deposits. It measures the very minute changes of gravity which may be positive, that is, increases, caused by the presence of heavier deposits, or negatives deficiencies caused by lighter deposits taking the place of heavier beds. In case of exploration for oil, the instrument is used indirectly, that is, not to locate oil deposits, which it is unable to do, but to locate oil structures favoring accumulation of oil in commercial quantities. In principle, it can be used with equal success for any type of oil structure, that is, salt domes, faults, anticlines, and intrusions. The greatest successes, however, have been obtained so far in the search for oil structures of salt dome type.

The instrument is limited by the necessity of presence of density difference between the beds, or structure looked for, and that of the overlaying strata. These differences do not need to be large, the instrument being sensitive to a degree not believable to the layman. This sensitiveness, unfortunately, represents an added limitation, that is, the desirability of a flat, or nearly flat surface, all hills and valleys having an effect on the instrument. This effect can and is being calculated at every station occupied, but, this compensation system has its limitations.

The instrument itself is a modification of the Cavendish Torsion Balance. The Cavendish instrument consists of a fine wire on which a horizontal beam is suspended, which beam carries 2 weights, masses, on its 2 ends. A torsion balance of this form will give information only about the deviation of the actual form of the earth's sphere, at a point, from an ideal form, called level surface, which theoretical information does not always have a practical, useful meaning. Eötvös modified this instrument in such a way that the 2 masses are not placed in the same horizontal level.

Fig. 1 illustrates the theoretical and actual form of the Eötvös instrument. This instrument measures not only the deviations from a theoretical surface, but furnishes us with a much more useful information, which is called a "gradient" representing the changes of the gravity per centimeter horizontal distance.

Fig 1

The formulae by means of which these data are calculated from the actual showings of the instrumenst are rather lengthy and can be taken from any of several textbooks.

Fig. 1 shows the working parts of the instrument. The torsion wire, which is really the foundation around which the field instrument is built, is made of platinum iridium. The present instrument, which represents a considerable reduction in size, carries a torsion wire of 40 cm length and .002 mm diameter. The torsion wires after being manufactured go through a very careful treatment at the Eötvös Geophysical Institute of Budapest. This treatment serves to take out the inherent instability of all wires, that is, it serves to make the wires react to the same extent to the same influences. These influences are the torque

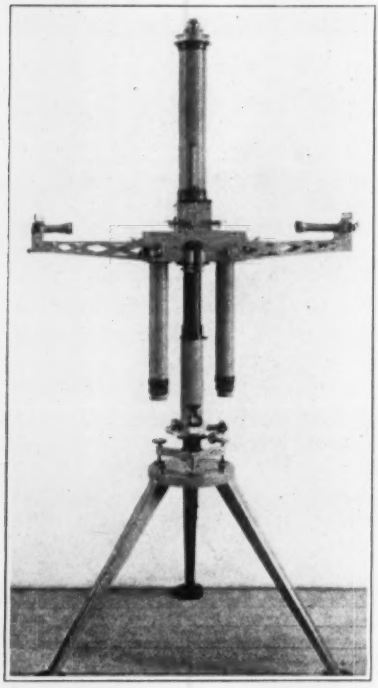


Fig. 2

caused by moment of forces acting upon the weights, and the displacement caused by changes of temperature.

Fig. 2 shows the field instrument as actually used. All instruments contain 2 entirely independent suspended systems as per Fig. 1. This serves to speed up the work, and cuts the necessary time actually to half of that if it had only 1 suspended system.

Although the instrument is about 5 feet high, it is the smallest instrument practically proven. The size is determined by the minimum dimensions of the suspended system, and the necessity of a minimum elevation above the ground to diminish immediate surface influences. The pedestal part of the instrument is self explanatory from Fig. 2, and it is nothing but a support bearing level vials and a graduated circle, to enable the observer to place the instrument in the prescribed azimuth. The upper tubes, beam box, and lower tubes are triple walled, to protect the working parts from sudden changes of temperature. The necessary mechanism to fasten and free the beams and lower weight, an adjustable support for the torsion wire, called "torsion head," completes the picture.

The behavoir of the instrument, that is, the turning of the torsion wire to certain angles, is observed by means of a mirror placed on the beam, and a scale reflected by this mirror. The optical arrangement to make such observations is also self explanatory in Fig. 2.

The actual use of an Original Eötvös Torsion Balance may be described briefly as follows: The instrument is set up at certain intervals, which is anywhere from 200 feet to 2 miles, according to the purpose and opinion of the users. A small portable insulated house is provided to protect the instrument from temperature, wind, etc. The instrument is placed in its first position usually magnetic North, suspended systems released, and the instrument left alone. After 50 minutes, which is the time necessary for the beams to come to rest plus a safety period, the observer enters the house, flashes light on the scale, notes the positions, temperatures, turns the instrument 120°. The same procedure is followed once more, which completes 1 set of readings. It is usual, however, to read in 2 more positions, at least, that is, 5 readings all told.

Eötvös-Rybar Torsion Balance

(George Steiner, Incorporated)

THIS instrument, in principle, is the same as the Original Eötvös Torsion Balance described above. The difference consists of a new torsion wire of different material, reduced in size, and an attachment to make the observations automatic and register them photographically.

Fig. 1

Fig. 2

Torsion wires used in the "Original Eötvös," are made of platinum iridium and are 40 cm long and 0.02 mm diameter. The wires in the Rybar instrument use alloys of tungsten group, are 20 cm long, 0.1 mm diameter, of equal, if not higher sensitiveness. The reduction in the dimensions of the suspended system allows the building of a smaller, handier field instrument. Some of the companies using torsion balances prefer to eliminate the human element of error of the visual observation and desire to obtain a photographic record of the indications of the instrument. Such a feature necessarily entails addition of mechanical movements complicating the torsion balance as a field instrument.

The Rybar instrument includes the feature of the automatic registration in a simple arrangement. The suspended beam systems are entirely disconnected from the parts containing the automatic mechanism, which results in the retaining of simple adjustments and change of wires. The turning of the instrument is effected by a single spring and regulator in such a way that it does away with the necessity of a separate clockwork to move

the photographic plate. A timer clock is furnished with the instrument which releases the timing device every 40 minutes. Stops are provided to orient the instrument in the necessary azimuths, and there is a small battery to furnish current for the bulb while taking a photograph of the beam.

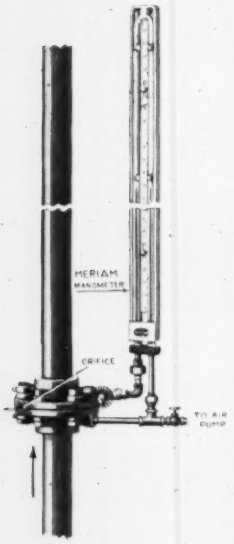
Should any difficulty arise with the automatic feature, it can be dismantled bodily from the instrument which can then be used as a visual instrument.

A visual attachment, that is, arms, telescopes, scales are furnished with each instrument. The Rybar instrument embodies, according to the makers, all advantages of both automatic and visual instruments.

Fig. 1 illustrates the instrument as used normally while Fig. 2 shows it with visual attachment, which is placed on the instrument in an extremely simple way.

Inverted Type Manometer For Measuring Liquids

MOST of us are familiar with the ordinary type of U-tube manometer in which the bend of the glass indicating tube is at the bottom. The inverted type however, is less often seen, although it possesses decided advantages in certain conditions for measuring the flow and pressure of liquids.



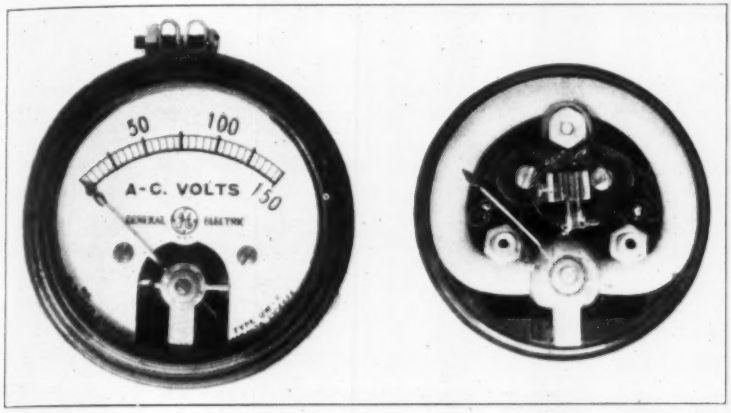
The inverted type manometer shown in the illustration and manufactured by The Meriam Company, differs little in construction from their ordinary types except that the bend of the U-tube is at the top instead of at the bottom. It is connected in the usual manner—one arm of the U-tube being piped to each of the points between which the pressure is to be measured, or in the case where rate of flow is to be found, to either side of an orifice disc of known size placed directly in the pipe line through which the liquid flows.

The chief difference between the inverted and the ordinary type is that the liquid levels in the two arms are the actual levels of the liquid measured, instead of being mercury or other special liquid placed in the tube itself. The main advantage of this method is that should the differential pressure be too great, there is no mercury to be "blown over" and lost. The liquid from one side will merely flow over to the other through the manometer till the pressure drops, when it is immediately ready for use again.

New Small-Size Panel-Type Instruments

(General Electric Company)

MINIATURE voltmeters and milliammeters, in $2\frac{1}{4}$ and 3" cases for use on both alternating and direct-current lines, have been introduced by the General Electric Company. The meters are provided with molded compound cases and bases, the case being threaded so as to screw on the base.



These small-sized D'Arsonval instruments are equipped with full-wave copper oxide rectifiers mounted inside the case. These rectifiers permit the instruments to be used on alternating current circuits and thus make it possible to provide alternating current instruments in low voltage and current rating having the high sensitivity, the low power consumption and the well-proportioned damping of the D'Arsonval element.

Voltmeters are supplied in ratings as low as 2 volts full scale. They have the advantage of high ohms per volt sensitivity, and are self-contained for normal capacities. It is possible to supply such instruments having resistance even as high as 4000 ohms per volt. Milliammeters are available in ratings from 0.5 to 15 milliamperes, with resistance from 1400 to 350 ohms.

The copper oxide rectifiers used have permanency characteristics which insure accuracy of the instrument over a long period. The inherent change in rectifier resistance resulting from temperature changes is negligible. Only for low or special capacities are the errors appreciable, but in general there is not more than 0.1% per degree Centigrade change in ambient temperature.

Frequency errors are negligible over the power frequency range of 25 to 100 cycles, and even with frequencies as high as 6000 cycles the errors are very small. The overload capacity is the same as for other D'Arsonval instruments. About the most serious limitations are possible wave-form errors; these must be given some consideration with the various applications.

In most measurements the r. m. s. (root-mean-square) values of the current and voltage are those desired in preference to the average values, since the

latter generally are of interest only in connection with electrolytic processes, such as the charging of batteries, and in magnetic flux measurements. This applies to alternating current as well as to direct current, either pulsating or continuous, except that for a continuous direct current the r. m. s. value is equal to the average.

In the electrodynamic and moving-iron vane instruments the torque or the deflection of the pointer is proportional to the r. m. s. value of current or voltage, while in the D'Arsonval type the deflection is proportional to the average values. It is clear that either one of the 2 classes of instruments can be calibrated for any current or voltage. The D'Arsonval instruments can be calibrated readily to indicate r. m. s. values, and will read correctly in this respect as long as the ratio between r. m. s. and average values (the form factor) of the current or voltage in question is the same as the ratio for which the instrument is calibrated. For a pure sine wave this ratio is 1.11 and has, therefore, been used as the basis for calibration of the instrument to be used for indication of r. m. s. values. Although only a very few commercial alternating current supplies have a pure sine wave form, the form factor is generally very close to the standard value of 1.11, and for this reason no serious errors are to be expected.

Wave form errors cannot be ignored in all cases, however, when considering applications for these instruments. If, for instance, the supply is from a small, highly saturated transformer, the readings obtained will not be true r. m. s. values. Likewise, an instrument cannot be read correctly on either alternating or direct current unless it is specially designed for this purpose.

Although, as already mentioned, the frequency errors are very small, they cannot be entirely overlooked. At radio frequencies, for example above 6000, the instruments will read low by a considerable amount, but the comparatively large frequency range over which they may be applied permits numerous applications in telephone work, radio, etc., where in general the available power for operating the instruments is very small.

The new instruments, known as Types DO-14X and DW 1-X, have specifications and ratings as follows:

	DO-14X	DW 1-X
Movement	D'Arsonval	D'Arsonval
Scale length	2"	$1\frac{1}{2}$"
Accuracy	3%	3%
Diameter over flange	$3\frac{1}{16}$"	$2\frac{1}{4}$"
Diameter over body	$2\frac{23}{64}$"	$2\frac{1}{16}$"
Height	$1\frac{5}{8}$"	$1\frac{23}{64}$"
Stud length	1"	1"

Milliammeters (Types DO-14X and DW 1-X)

Milliamps.	*Resistance in Ohms, approx.*
0.5	1400
1	900
2	700
3	600
5	500
10	400
15	350

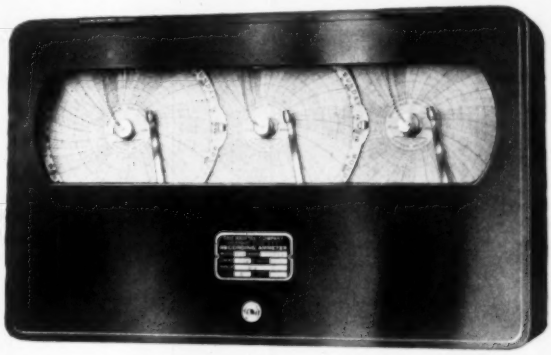
Voltmeters (Types DO-14X and DW 1-X)

Volts.	*Resistance in Ohms, approx.*
2	3600
3	5400
5	9000
6	10800
10	18000
15	27000
25	25000
50	50000
100	100000
150	150000

New Triplex Ammeter

*Perry A. Borden**

THE Bristol Company has added to its line of recording instruments a triplex ammeter, developed in response to the demand from the electrical utilities for a compact recorder to be used in unattended substations, furnishing a continuous chart of currents in all three lines of polyphase feeders. While no radically new electrical or mechanical principles are involved, and all features of design have been proved by years of service, the instrument possesses a number of interesting and original points which should commend themselves to those charged with the distribution of electrical energy.



The measuring elements in this instrument are of the moving-iron type, the armatures taking the form of attracted discs, built up on an alloy selected with an especial view to high permeability and low losses. The moving part is carried upon simple knife-edge springs, and lies in the field of a short compact solenoid. The whole construction of this essential part makes for simplicity, ruggedness and efficiency.

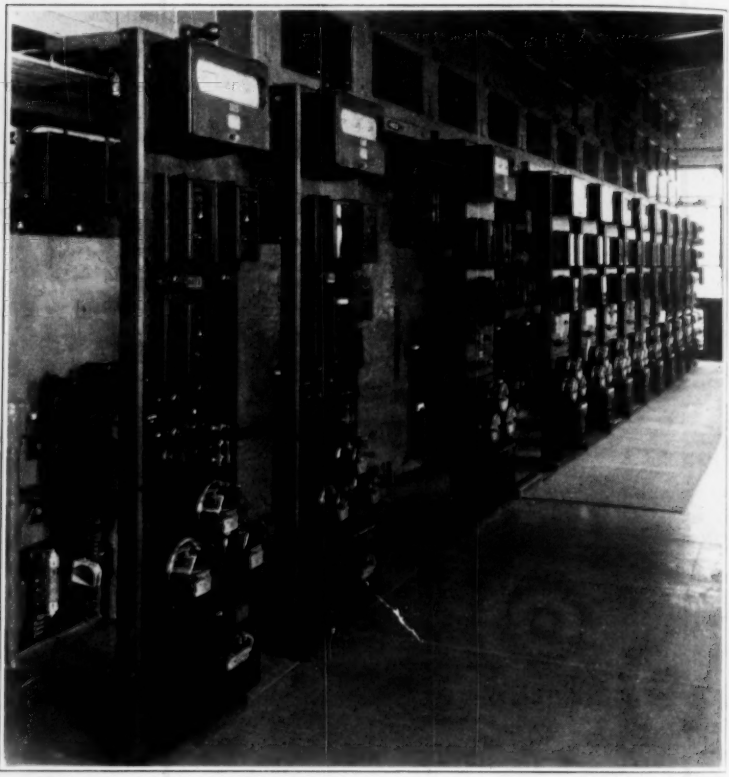
Records are obtained on three standard six-inch round charts, arranged in a horizontal line, but overlapped in such a way that, while the active portion is in plain sight, the whole width of the instrument permits its installation on an eighteen-inch panel. The standard speed for the charts is 1 revolution in 7 days; and a reservoir type of pen is provided, assuring an ample supply of ink for the week's operation. A chart hub is driven through worm gearing from a common shaft, whose motive power is a Warren synchronous motor, such as is used in the well-known Telechron clocks.

In the design of the instrument the feature of unit construction has been kept in view; and it is possible to remove any of the measuring elements or the whole chart-driving mechanism as a unit, without disturbing the adjustments of other parts of the instrument.

The Triplex instrument is contained in a substantial die-cast case, approximately 17 by 10½", by 5" deep, and as already stated, suited for installation on a standard 18" panel. The wiring is arranged for back con-

*Engineer, The Bristol Company

nection, with studs projecting through the switchboard. It is possible, however, where it is desired to minimize the amount of drilling, to remove the studs and connect directly to the rear of the instrument, there being sufficient clearance between the base plate and the surface of the panel to permit of bringing the leads to a single opening. The standard finish of the case is a "rubber" black harmonizing well with slate or composition panels. A single cover, hinged at the top, exposes the whole interior for inspection and for changing the charts; and when this is closed the three records are distinctly visible through a glass window of ample dimensions.



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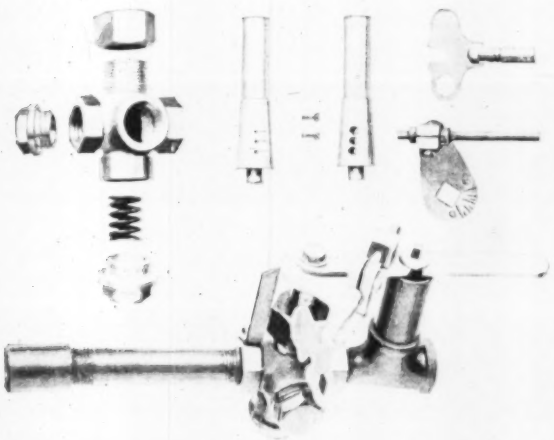
Plug Type Valve

(Automatic Temperature Control Co.)

A valve which will be of interest to every manufacturer and user of oil fired furnaces is a plug type designed for either manual or automatic operation.

Cut below shows rugged construction of the parts and the simplicity of design.



The valve lever is locked in position with a key furnished with the valve and this key is also used to adjust the valve position for desired oil flow, very minute changes in position being possible with the finely threaded adjusting screw.

Dial plate and index shows amount of valve opening at all times and permits quickly duplicating a previous valve setting.

To meet normal oil conditions, this valve is provided with three, sixty degree tapered V shaped grooves which are accurately machined on circumference of the plug and terminate in holes through the plug 52, 46 and 41 drill size respectively. Orifice screws or field plugs are provided so that the holes not required may be plugged and capacity of the valve adjusted to give best results for a given application.

Capacity of this valve may be altered in the field without removal from the line. To accomplish this, the stem should be turned so that valve is in a closed position as shown by index and dial plate then unscrew cap on side of valve body and with a small screw-driver remove or change position of the field plugs, bearing in mind that the largest orifice is at the bottom while the smallest is at the top.

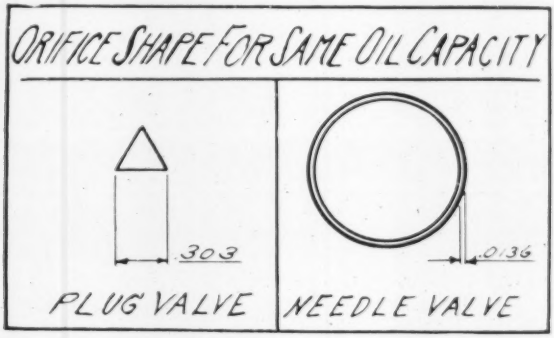
With oil 20 to 30 Baume at a temperature of 60°F. and a pressure of 25 lbs., a maximum of 30 gals. per hr. can be handled with the smallest orifice. Under the same oil conditions, all three of the orifices have a combined capacity of 120 gal. per hour. For special grades of oil, this valve can be provided with orifices of a size to meet the conditions.

Compared to a needle valve opened for the same capacity, liability of clogging is greatly reduced in this plug type valve as shown by the following calculations:

The smallest orifice in this plug valve is a $\frac{1}{16}$" hole made with a No. 52 drill which gives an area of .0030 inches and as stated, this orifice tapers off in a 60-degree V-shaped groove on circumference of the plug. Using this orifice at one half capacity, the triangular groove has an area of approximately .0017 sq. inches and a length on each side of the triangle of .063 inches.

A needle valve having a $\frac{1}{16}$" diameter seat, or a total area of .0276 sq. inches when reduced to the same capacity (namely an area of .00173 sq. inches) must have a plug or needle area of .02587 sq. inches which gives the annular space between plug and seat a width of but .00375 inches.

Diagrams below show just what the above figures mean with valve openings magnified 25 times.



From the above, it is evident that the plug type V port orifice valve will pass hairs and sediment many times the size that would barely pass a needle valve of similar capacity.

In addition to minimizing clogging by shaping the area of opening like a triangle, this construction gives a gradual change of oil volume proportional to motion of the valve lever.

In case of clogging, this plug type valve may be quickly flushed by loosening the locked valve lever, swinging full open and again locking back in its original position. Should this plan not completely clean the valve, the stem may be turned to full closed position, side cap removed and a fine wire inserted through the orifice.

The inverted plug is ground fitted in the valve body and is held in uniform tension from below by the heavy spring shown. This construction prevents any possibility of the plug seizing or of oil leaking past the grooves.

The valve stem is gland packed and oil flow may be in either direction.

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APPARATUS FOR TESTING PETROLEUM PRODUCTS. 52 page bulletin lists products with prices. A. Gallenkamp & Co., London, E. C. 2, England.

BAKELITE REVIEW. The January issue shows a number of applications of Bakelite. Its application to scale pans by the W. M. Welch Scientific Co. is illustrated. Bakelite Corp., 247 Park Ave., New York, N. Y.

BALANCES. Very complete bulletin of analytical balances and weights. Julian H. Becker, Delft-Holland.

BUMSTEAD SUN COMPASS. Leaflet covers construction, installation and operation of this instrument. Pioneer Instrument Company, 754 Lexington Ave., Brooklyn, N. Y.

CHEMICAL MICROSCOPE. Leaflet illustrates the new chemical microscope designed by Drs. Chamot & Mason. Spencer Lens Co., Buffalo, N. Y.

CARBON CIRCUIT BREAKERS. 20 page circular illustrates installations and construction. Circular 1705-B. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Control Instruments. Bulletin shows thermometer, controls, gas and air meters, chemical measuring instruments. This is printed in German. J. C. Eckardt, A. G., Stuttgart, Germany.

COLORIMETER. Leaflet describes the Pfund Multiple Reflection Colorimeter. Munsell Color Company, Inc., 10 East Franklin Street, Baltimore, Md.

CHECK FLOW AS A CASH REGISTER CHECKS DOLLARS. Leaflet covers the new Brown integrating flow meter. Full size illustration is given. Brown Instrument Company, 4482 Wayne Street, Philadelphia, Pa.

DIAL-MIKE. Leaflet illustrates the new Ames "Dial Mike." B. C. Ames Co., Waltham, Mass.

DRIFTMETER. Leaflet describes an instrument which records on the derrick floor of an oil well the angle of deviation from the vertical. Driftmeter, Inc., 616 Exchange Bank Bldg., Tulsa, Okla.

DETACHABLE WATTHOUR METERS. Leaflet covers application, distinctive features, operation and construction. Westinghouse Elec. & Mfg. Co., Newark, N. J.

ELECTRICAL INSTRUMENTS. 16 page bulletin describes the direct current instruments of the Heyer Products Company, Bloomfield, N. J.

FORTY YEARS AGO. Booklet is a brief account of the history and accomplishments of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

GENERAL RADIO EXPERIMENTER. The January 1930 Issue of the Experimenter contains the following article: An Equal-Arm Capacitance Bridge. General Radio Co., Cambridge A, Mass.

GAS METERS. Bulletin No. 165 covers the Foxboro Gas Meters for industrial and similar loads. Foxboro Company, Foxboro Massachusetts.

GAS ANALYTICAL APPARATUS. Catalog-77 describes the standard Burrell gas analysis electro analysis and testing apparatus. Burrell Technical Supply Co., 1700 Fifth Ave., Pittsburgh, Pa.

GENERATOR TEMPERATURE RECORDER. Leaflet illustrates the L & N generator temperature recorder. Leeds & Northup Co., 4901 Stenton Ave., Philadelphia, Pennsylvania.

HARDNESS METER FOR VARNISHES AND PLASTIC FILMS. Leaflet gives information on the Pfund Hardness Meter. Munsell Color Company, 10 E. Franklin Street, Baltimore, Md.

INSTRUMENT INVESTMENT NEWS. The February issue contains the following articles: Modern Gauge Board for a Modern Building; Where Gauge Accuracy is Paramount; Power Control Means Cheaper Power. Consolidated Ashcroft Hancock Co., Bridgeport, Conn.

LABORATORY. Volume 3, No. 1 contains the following: Time; Quantitative Chemical Spectroscopy; To Save Time is Drying Operation; etc. Fisher Scientific Co., 711 Forbes Street, Pittsburgh, Pa.

MOTOR STARTING AMMETER. Leaflet 20400 describes the application, operation and construction of the type PY-5 motor starting ammeter. Westinghouse Elec. & Mfg. Co., Newark, N. J.

MICROSCOPE RECORD. The January 1930 Issue Contains the following articles: Current Microscopy; The One-Sixth Objective; Hints to Beginners; Measuring the Thickness of an Object. W. Watson & Sons, Ltd., 313 High Holborn, London, W. C. 1, England.

OIL CIRCUIT BREAKERS. Circular 1828 contains several photographs and drawings, and describes in some detail the types G-22-S, G-222-S, and G-22-AS. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

PHOTOELECTRIC SPECTROPHOTOMETER. Reprint describes the new instrument. American Photoelectric Corporation, New York, N. Y.

PRICE LIST-CHEMICALS. List shows prices of industrial chemicals of J. T. Baker Chemical Company, Phillipsburg, N. J.

PRECISION INSTRUMENTS FOR AUTOMATIC LABORATORIES. Folder contains descriptions manufactured by the Commercial Engineering Laboratories, Detroit, Michigan.

PHOTOMETER. Leaflet describes the Munsell Universal Photometer. Munsell Color Company, 10 East Franklin Street, Baltimore, Md.

PORTABLE STANDARDIZING SET. Circular illustrates the L & N portable standardizing set, which is unaffected by stray fields. Leeds & Northup Company, 4901 Stenton Ave., Philadelphia, Pa.

RECORDING CONTROLLERS. Leaflet illustrates the installation of recorder-controllers at the Wright Aeronautical Corp. for controlling carburizing furnaces. Leeds & Northup Co., 4901 Stenton Ave., Philadelphia, Pa.

STEAM METER. Direct Mail folder illustrates the new Foxboro steam meter. Foxboro Co., Foxboro, Mass.

SOILS BRIDGE FOR TESTING SOILS AND SOIL SOLUTIONS. Leaflet illustrates this instrument. Leeds & Northup Co., 4901 Stenton Ave., Philadelphia, Pa.

STEAM JET EXHAUSTERS AND COMPRESSORS. Bulletin 4-E illustrates and describes the exhauster for laboratory use. Schutte & Koerting Co., Philadelphia, Pa.

WATER JET EXHAUSTERS & COMPRESSORS. Bulletin 4-P describes and illustrates this apparatus. Schutte & Koerting Company, Philadelphia, Pa.

SPECTROSCOPY. An 18 page booklet entitled "The Detection and Investigation of Poisons by Spectroscopy" discusses the application of spectroscopy to the determination of the presence of organic and metallic poisons in food products. Adam Hilger Ltd., 24 Rochester Place, Camden Road, London NW 1.

TESTING EQUIPMENT. This 62 page loose-leaf booklet gives considerable very interesting information on Southwark-Emery Testing Equipment. Arguments for and against the hydraulic testing machine are included in Section I. Section III begins with the first horizontal Emery machine built by the War Department at the Watertown Arsenal in 1875 and traces the development of the company in a brief historical sketch. The Emery weighing system, dial indicator and loading system is covered in some detail. For recording, either recorders of Brown Instrument Company or the Leeds & Northrup Company can be used. Design, installation, maintenance and calibration are covered. Various models are illustrated. Southwark Foundry & Machine Co., 400 Washington Ave., Philadelphia, Pa.

TYCOS ROCHESTER. The January 1930 issue of this publication contains the following very interesting articles: Science Surveys the Snows; Overcoming Greatest Foe to Aviation; Airmail Pilots no Longer at Mercy of Weather Elements; Our Regions of Deepest Snowfall and The Hygrometer in Home and Industry. Taylor Inst. Companies, Rochester, N. Y.

SERVICE INSTRUMENTS THAT BOOST RADIO PROFITS. Form 2098 illustrates the Pattern 409 and Pattern 199 Radio Set Analyzer. Jewell Electrical Instrument Co., 1650 Walnut St., Chicago, Ill.

TELEGAGE. Ex 5183 illustrates a large number of applications of the K-S hydrostatic distant reading gage. King-Seeley Corporation, Ann Arbor, Mich.

TINTOMETER. Leaflet gives method of using Lovibond's Tintometer for the washing test on low boiling fractions from coal tar. The Tintometer, Ltd., 1, The Friary, Salisbury.

THWING PYROMETER. F-95 announces the features of the new Model 30 Thwing Pyrometer. Thwing Pyrometer Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.

POTENTIOMETER RECORDING PYROMETER. Catalog Section P-1929 describes an extensions of the Wilson-Maeulen line of pyrometers. This recorder employs the potentiometer principle for temperature measurement. Wilson-Maeulen Co., Inc., 387 Concord Ave., New York, N. Y.

ELECTRICAL ENGINEERING ACHIEVEMENTS. Special Publication 1717D entitles "Engineering Achievements of the Westinghouse Electric & Mfg. Co. covers the work of Westinghouse during 1929. The articles of most interest to those interested in measurements are: Many ingenious Devices Use the Electric Eye; a Means of Measuring Ultra-Violet Rays; Testing Customers' Meters at the Central Station; and a New Weapon Against Heart Disease. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GAS SERVICE JOURNAL. The December issue of this publication contains the following: Installation of a 12" Emco Governor at the Front Street Station of the Brooklyn Union Gas Co.; The Properties of Liquefied Petroleum Gases as Affecting Their Uses; and Field Estimating for Rate of Flow Through Orifice Meters. Pittsburgh Equitable Meter Company, 101 Lexington Ave., Pittsburgh, Pa.

GENERAL RADIO EXPERIMENTER. The December Experimenter contains the following: Television: A Comparison with Other Kinds of Electrical Communication; Gain in Amplifiers and Other Networks. Genral Radio Company, 30 State Street, Cambridge, Mass.

INSTRUMENT INVESTMENT NEWS Luncheon in a Boiler; Instruments-the Entering Wedge; In the Oil Industry; Cold Storage Temperature Standards; and Accurate Temperature Control. Consolidated Ashcroft Hancock Co., Inc., Bridgeport, Conn.

INSTRUMENTS FOR TEMPERATURE MEASUREMENT AND CONTROL. The Red List gives information on the standard range of temperature measuring instruments. This is printed in English. Hartmann & Braun A. G., Frankfurt a. M., Germany.

MICROMETERS. Catalog 8 gives information and prices on the micrometers and small tools of Reed Small Tool Wks., Worcester, Mass.

PORTABLE ELECTRICAL INSTRUMENTS. The Brown List gives information and prices on portable measuring instruments for laboratory and industrial measurements. This is printed in English. Hartmann & Braun A. G., Frankfurt a. M., Germany.

RECORDING PRESSURE AND VACUUM GAUGES. Catalog 1009 replaces Catalog 1005. It gives information on the various types and ranges, lists the charts and prices. The Bristol Company, Waterbury, Conn.

RESISTANCE METER. Circular DD Leaflet illustrates the Model 506 Resistance Meter. Weston Electrical Inst. Corp., Newark, N. J.

CONTINUOUS PLANT SURVEYS. Bulletin 1229 gives general information on the use of graphic instruments for plant surveys. Esterline-Angus Company, Indianapolis, Ind.

DIRECT READING RADIO TUBE TESTER Leaflet DS-526 gives the general characteristics of the Model 526 and the method of using it for testing. Weston Electrical Instrument Corp., Newark, N. J.

ELECTRICAL LABORATORY INSTRUMENTS. Green List contains descriptions, informations and prices on electrical laboratory instruments. Hartmann & Braun A. G., Frankfurt a. M., Germany. This is printed in English.

WARM AIR FURNACE FAN CONTROL Bulletin A-5 fully describes the construction and uses of the control. Mercoid Corporation, 564 West Adams Street, Chicago, Ill.

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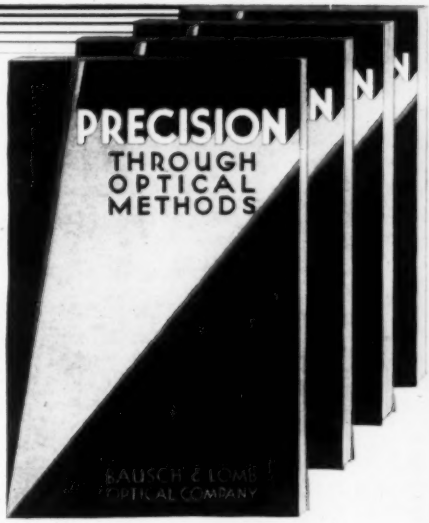

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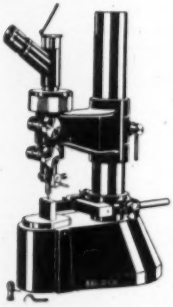

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CURRENT LITERATURE REVIEW

Abstracts on instruments and devices for measurement, inspection and control.

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MISCELLANEOUS

The Determination of the Flash Point (Zur Frage der Flammpunktbestimmung). J. Terpogos. Petroleum, August 21, 1929, pages 1161-1163.

The author reviews the latest improvements of the original Marcusson flash point tester and compares practical results from the laboratory with the Cleveland and Pensky-Martens method. —E. F.

Automatic Cut-off Device for a Gas Fired Laboratory Mercury Still. Ward E. Kuentzel. Journal American Chemical Society, Nov. 1929, pages 3349-3351.

Diagram and description are given of a cut-off device which enables the operator to start the still and go about other work. When the mercury runs low, the gas is automatically shut off.—M. E. H.

New Methods and Apparatus for the Examination of Molding Sands. (Neue Methoden und Apparate fur die Formsanduntersuchung auf der 5. Giesserei-Fach-Ausstellung Dusseldorf). Giesserei-Zeitung, Oct. 15, 1929, pages 594-595.

Description and application of apparatus to determine moisture, permeability of gases, plasticity and strength of molding sands. Description of vibrators built by Strohlein & Co. G. m. b. H. Dusseldorf, to determine content of alumina and grain size of sands. G. N.

A Simple Laboratory Vacuum Regulator. Ward E. Kuentzel, Journal American Chemical Society, Nov. 1929, pages 3347-3349.

A device for controlling the degree of vacuum and thus the temperature in the range from room temperature to red heat, by means of a vapor-bath with boiling liquid, is described. It is similar to the device described by S. P. Miller and P. V. McKinney, Ind. Engg. Chem., 20, 552 (1928). It is stated that the apparatus may readily be adapted to the control of vacuum distillations and other work in which a constant vacuum is desired.—M. E. H.

Investigation of Endurance of Bond Strength of Various Clays in Molding Sand. Carl H. Cadwell & William H. Spencer. Bulletin No. 200, Engineering Experiment Station, University of Illinois.

This bulletin contains a study of various clays in order to compare them for endurance of bond strength when used as bonds in molding sands under casting conditions.

Platinum-Group Metals in Product Design. Frederick E. Carter. American Machinist, Nov. 14, 1929, pages 822-824.

This group consists of the metals platinum, iridium, osmium, palladium, rhodium, and ruthenium. These metals are very highly resistant to corrosion. Because of this they are used for surgical instruments, electrical contact points, precision-type resistances, standard weights, thermocouples and like instruments. These alloys are useful for plating instruments, fine hardware and jewelry. Cheaper alloys of the platinum group using copper, cobalt or nickel are now available and are being used for many things.—R. H. P.

Durability Tests of Spar Varnishes. C. L. Came, Bureau of Standards Journal of Research, Feb. 1930, pages 247-257.

Fifty commercial spar varnishes, which had been tested for conformity to Federal specification No. 18b, were exposed to several accelerated weathering cycles and outdoors. Kauri reduction values were also determined. The varnish was applied both by whirling and brushing. Sand-blasted and non-sand blasted panels were used. This paper correlates the tests mentioned above and also gives the results of similar tests made on experimental varnishes, prepared in the laboratory from various oils and resins. A short bibliography pertaining to the subject matter of this paper is appended.

Effect of Small Changes in Temperature on the Properties of Bodies. Mayo D. Hersey. Bureau of Standard Journal of Research, Jan. 1930, pages 137-156.

When it is found necessary to determine the effect of small departures from normal temperature upon some property of a body or system of bodies, such as the stiffness of a steel spring, the vibration frequency of a tuning fork, or the accuracy of an instrument, it is usually done either (a) by a detailed computation or (b) by a direct experiment in which the temperature is actually varied. After reviewing and illustrating the usual methods of solution a general mathematical treatment of the problem is given, from which two additional methods are derived that can sometimes be usefully applied: (a) A simple calculation, made possible by the theory of dimensions, which does not require any detailed formula for the property in question; and (b) a combined theoretical and experimental solution, in which the experimental factors have been reduced to a minimum and can be determined without varying the temperature of the body itself, provided the thermal properties of the component materials are known. Finally, it is pointed out that the same treatment can be extended to any other condition analogous to temperature, such as hydrostatic pressure.

Further Experimental Production of Currency Paper in the Bureau of Standards Paper Mill. Merle B. Shaw & George W. Bicking. Bureau of Standards Journal of Research, Dec. 1929, pages 899-926.

The work continues the investigation to improve the durability of United States currency paper previously reported in Technologic Paper No. 329. The wear-resistant quality of currency paper was very much increased as a result of the experimental tests described in the earlier publication, but additional study of the paper-manufacturing processes with a view to further prolonging the service life of the currency was subsequently requested. The research was conducted in cooperation with the Bureau of Efficiency and the Bureau of Engraving and Printing. Comparative tests of commercial manufacturing procedure and bureau practice were made at the request of manufacturers desiring to produce paper of the type developed in the investigation. The experimental procedure gave equally good results with commercial equipment, and paper of similar quality is now being made commercially. Description of the manufacturing procedure, tables of experimental data, and discussion of the results are included in the publication.

Ceramic Investigations at the Bureau of Standards. Ceramic Age, Dec. 1929, pages 205-214.

Report of work on ceramics at Bureau of Standards.

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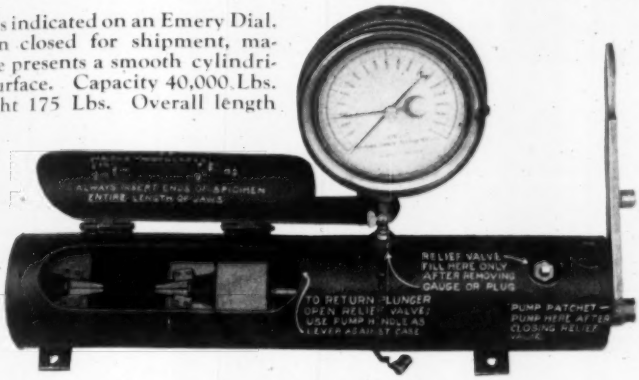

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Designing Large Telescopes. J. W. Fecker. Scientific American, Sept. 1929, pages 237-2
A very interesting article on the optical and mechanical problems involved in the construction of large telescopes.—Abs. Bull. Kodak Res. Labs.

Introducing and Removing Photographic Plates and Films Used with the Cathode Ray Oscillograph without Disturbing the High Vacuum. P. Hochlaeusler. Elektrotechnische Zeitschrift, June 13, 1929, pages 860-864.
Three methods are described.

Electrical Method for Measuring the Concentration of Suspensions. A. Slavinski. Journal de Chimie Physique, July 1929, pages 368-373.
The method is based on the fact that the conductivity of a liquid containing a suspension changes differently depending on whether the tube container is placed horizontally or vertically during sedimentation. Observed and calculated values agree quite well.—Abs. Bull. Kodak Res. Labs.

An Improved Differential Dilatometer. M. Haas & D. Uno. Instrument World, Oct. 1929, pages 163-164.
Paper read at the Dusseldorf meeting of the Institute of Metals. The accuracy of Chevenard's optical-differential-dilatometer has been improved by mounting the apparatus on a triangular frame but using 1 dilatometer tube instead of 2, and by replacing the spring that holds the mirror by a magnet coil arrangement.—M. B. R.

The Influence of Depolarization upon Corrosion Speed and Its Practical Application. (Der Einfluss der Depolarisation auf die Rostgeschwindingkeit und ihre praktische Nutzanwendung.) F. Toedt. Korrosion & Metallschutz, Aug. 1929, pages 169-174.
The author details his investigations which led to new corrosion meter.—E. F.

Comparing Investigation of Transition Resistance and Rust Protection Effect on Protected Iron Pipes (Vergleichende Untersuchungen von Uebergangswiderstand und Rostschutzwirkung an oberflaechengeschuetzten Eisenrohren) W. Beck & K. Jakobsohn. Korrosion & Metallschutz, Sept. 1929, pages 202-207.
The apparatus of Haber and his co-workers for the determination of transition resistance as a criterion of rust protection materials was modified by the authors in their practical investigations described in this paper.—E. F.

SPECIAL

The Ring and Ball Method of Test for Softening Point of Bituminous Materials, Resins, and Similar Substances. Percy H. Walker. Bureau of Standards Journal of Research, February 1930, pages 195-201.
The softening point of materials which, like asphalt, have no definite melting point, but which when heated gradually change from brittle or very thick and slow-flowing materials to more mobile liquids, can only be determined by some arbitrary method. The ring and ball method which briefly consists of determining the temperature at which a disk of the material held in a ring and loaded with a ball will flow through a definite distance when heated at a prescribed rate is one of the best methods for such tests. Published directions for making the test are, however, open to very serious objections, and this paper describes the apparatus and procedure used at the National Bureau of Standards. The principal modifications in the apparatus are a beveled instead of a cylindrical ring, and a centering device for the ball. The procedure is so described that some latitude in non-essential details is permitted.

Factor Influencing the Speed of Intensifying Screens. Frank E. Swindells. Journal Optical Society, Feb. 1930, pages 51-61.
The speed of intensifying screens was measured at three arbitrary densities by a sensitometric method. The screen factor was found to increase with shortened development time; to increase with increase of tube potential; to be independent of the tube current from 2 to 35 ma, to be independent of the target film distance from 0.5 to 2.5 meters; to increase as more filtering metal was interposed between the tube and screens; and to vary considerably with the photographic emulsion used. The increase with increasing potential is explained as the effect of the various energy losses of x-rays of different wave lengths when passing through the front screen, and also the different relative abilities of x-rays of different wave lengths to excite fluorescence, and to expose silver bromide. The variation of the speed factors with different emulsions is due to different relative sensitivity of the screens to x-rays and to the fluorescent light from the screens.

Turning with Shallow Cuts at High Speeds. H. J. French & T. G. Digges. Bureau of Standards Journal of Research, Dec. 1929, pages 829-898.
A method is described for testing lathe tools under shallow cuts and fine feeds. The relations were determined between the cutting speed, feed, depth of cut, and tool life for carbon and high-speed tool steels. Comparisons were made of tools of different forms and of tool life when cutting dry and with water or lard oil. Heat treatment and chemical composition of the tools were also studied, including, in the case of high-speed tool steels, the effects of cobalt, nickel, molybdenum, arsenic, antimony, phosphorous, sulphur, copper, tin, aluminum, titanium, and tantalum. The results obtained under shallow cuts and fine feeds with these steels are compared with those obtained under heavy duty.

"Synchrometer" Brake-Testing Machine. American Machinist, Oct. 31, 1929, pages 760-761
This testing machine is intended to reproduce road conditions. Power from the vehicle drives 4 flywheels at a certain speed. The brakes are then applied. An indicator coupled to each flywheel records the distance which each wheel actually travels before stopping.—R. H. P.

Measurement of Evaporation. A. G. Rendall. Paper Makers' Monthly Journal, May 15, 1929, pages 190-192.
The close similarity between the rate of evaporation of water curves and those representing the difference in vapor pressure of ether in wet and dry bulbs has been made the basis of an instrument for measuring the "drying potential" of the air.—Abs. Bull. Kodak Res. Labs.

Exhibition of an Apparatus for Measuring the Thermal Expansion of Glass from Room Temperature to the Softening Point. F. Winks. Proceedings Physical Society, London, Aug. 15, 1929, pages 588-590.
A method of comparing the lengths of a glass rod and a fused silica rod at high temperatures. The method appears accurate and reliable.—Abs. Bull. Kodak Res. Labs.

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Thermometric Method of Measuring the Efficiency of Hydraulic Turbines (Methode thermometrique de mesure du rendement des turbines hydrauliques). L. Barbillion. Revue Generale de l' Electricite, Sept. 28, 1929, pages 487-497.

Author, in collaboration with Poirson had devised a method for determining the efficiency of hydraulic turbines, based on the measurement of a difference in temperature. In this paper he discusses its modification for special cases. These may be classified as : (1) "thermomanometric" based on the measurement of the pressure when the difference in temperature has been reduced to zero; (2) "thermometric," proper, in which only measurements of temperature are made; and (3) "calorimetric," based on the measurement of the quantity of heat in the water. For each particular case, he gives details of the arrangements to adopt, the procedures to follow, and the precautions to take.—M. S.

Gyroscopic Turn Indicator for Aeroplanes. Electrical Review, Nov. 29, 1929, pages 971-972.

Brief description of the Schilovsky-Cooke device, introduced by Aircraft Patents, Ltd. Intended as an aid in the maintenance of an accurate course. Shows a band of red light when aeroplane turns to left, and a green light when it turns to right. Extent of band indicates rate of turn.—M. S.

Porosity Testing Device for Air Corporations. Aero Digest, Jan. 1930, page 136.

An apparatus for calculating the amount of air passing per minute through fabric has been devised by the Material Engineers of the Bureau of Aeronautics assisted by the Bureau of Standards. It is for use in determining the porosity of material used in parachute construction.—M. L. M.

Sperry Automatic Pilot. Aero Digest, Dec. 1929, page 166.

A new automatic pilot "Mecaviator" manufactured by the Sperry Gyroscope Co., is described. The instrument is small and compact and sensitive to a change of movement of $\frac{1}{2}^{\circ}$ of the airplane about its axis. Its purpose is merely to control an airplane in straight and level flight and to hold it in a given course.—M. L. M.

Course-shift Indicator for the Double-Modulation Type Radio Beacon. Aero Digest, Dec. 1929, pages 168-170.

Abstract of Bureau of Standards Research paper by H. Diamond & F. W. Dunmore. A course-shift indicating instrument, primarily for station use is described. It may also be used as a visual course indicator on large aircraft. Its advantages and disadvantages as compared with the vibrating reed indicator are discussed in Research Paper no. 77.—M. L. M.

Practical Arrangement of Meters for Stack Gas Testers Destined for the Evaluation of Stoker Premiums. (Zweckmaessige Anordnung von Zahlern fur Rauchgaspruefer zur Ermittlung von Heizerpremien). Siemens Zeitschrift, Aug. 1929, pages 514-515.

The electrolytic counter in which hydrogen serves as a measuring medium is mounted in parallel with the flue gas tester.—E. F.

Effects of Temperature and Pressure on the Upper Explosive Limit of Methane-Oxygen Mixtures. C. M. Cooper & P. J. Wiezevich. Industrial & Engineering Chemistry, Dec. 1929, pages 1210-1214.

A new apparatus of the make-and-break type has been developed for the ignition of gaseous mixtures at high temperatures and pressures. With this apparatus the explosive limits of methane-oxygen have been investigated at pressures up to 230 atmospheres and temperatures up to 480°C.—M. E. H.

An Electrical Bubble Counter. Further Experimental Tests of the Gibbs Adsorption Theorem. The Structure of the Surface of Ordinary Solutions. James W. McBain & Robert DuBois. Journal American Chemical Society, Dec. 1929, pages 3534-3549.

The adsorption tube is shown with a bubbling nozzle which is equipped with a circuit breaking device consisting of two platinum wires sealed into glass tubes on opposite sides of the nozzle and arranged so that the bubble, on passing, is pierced by the wire tips. The gap is thus bridged by a non-conducting gas. The wires form part of the grid circuit of a three-electrode vacuum tube.—M. E. H.

Absolute Measurements of the Surface Conductivity near the Boundary of Optically Polished Glass and Solutions of Potassium Chloride. James W. McBain, Charles R. Peaker & A. Millicent King, Journal American Chemical Society, Nov. 1929, pages 3294-3312.

For the first time absolute measurements of specific surface conductivity have been made. The cells are described.—M. E. H.

An Apparatus for Testing Duhring's Law for Corresponding Boiling Points. Erwin F. Linhurst. Journal American Chemical Society, Nov. 1929, pages 3262-3265.

The apparatus provides for the boiling of two liquids in different parts of a closed system under variable pressure. Diagram is given.—M. E. H.

Permeability of Rubber to Air. I-Effect of Temperature, Pressure and Humidity. V. N. Morris & J. N. Street. Industrial & Engineering Chemistry, Dec. 1929, pages 1215-1219.

Apparatus and procedure are described for investigating the influence of temperature, pressure and humidity upon the capacity of rubber membranes to retain air under pressure.—M. E. H.

Instrument to Measure Contraction. (Vorschlag fur ein Messgerat zur Bestimmung der Kontraktion). F. Honig von Honigsberg. Stahl und Eisen, Dec. 12, 1929, pages 1800-1801.

The instrument, sold by Mohr & Federhaff, permits the simple accurate determination of diameter changes of test samples while being stretched or compressed.—G. N.

Electrification and Electrical Conductivity of Liquid Hydrocarbons (Electrisation et conduction electrique des hydrocarbures liquids). L. Bruninghaus. Rev. Gen. de l'Electricite, Nov. 16, 1929, pages 787-795, Nov. 23, 1929, pages 831-839, Nov. 30, 1929, pages 871-884.

Investigation of the phenomena of electrification of hydrocarbons flowing along the side of a metallic pipe. Demonstrates that the electrification of hydrocarbons is a function of their electrical conductivity. Describes apparatus used in measuring the conductivity and gives results.—M. S.

Sludge Testing Apparatus for Insulating Oils. Electrician, Nov. 29, 1929, page 662.

An apparatus devised by the Metropolitan-Vickers Electrical Co., Ltd. for determining the relative sludge-forming tendencies of various classes of insulating oils under conditions designed to represent as nearly as possible those obtaining in service. The test consists in submitting a measured quantity of oil for a standard time to the combined influences of heat, contact with air and a catalyst. Actual control of details of manipulation is essential. The method of air-flow control and measurement consists of a calibrated capillary tube so arranged that the pressure drop across its ends when air is passing through it can be readily measured and adjusted. The apparatus is illustrated.—W. H. B.

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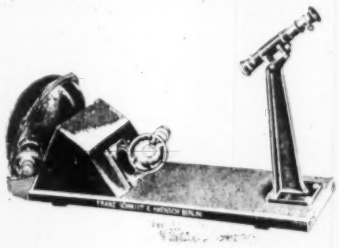

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CALCULATING DEVICES AND METHODS

A New Instrument for the Mechanical Calculation of the Conductors of Overhead Electric Lines (Un appareil nouveau pour le calcul mecanique des conducteurs des lignes electriques aeriennes.) J. Musyck. Revue Generale de l'Electricite, Oct. 5, 1929, pages 535-540.

Permits an easier determination of sag and tension. Based on a method of solution proposed by the author in 1924. Comprises, in principle, a single curve drawn on a sheet of paper which is fixed and on which are laid two rules, one of which may be moved parallel to the axis of abscissas and the other rotated about a point of the first. The forces are read directly from a group of straight lines, drawn on a transparent surface, which is an integral part of the first rule.—M. S.

Integration of "Orifice Head" Charts by Means of Special Planimeters. John L. Hodgson. Journal of Scientific Instruments, Sept. 1929, pages 294-297.

Two special planimeters are described which enable the charts of recording flow-meters to be integrated much more readily than is possible when ordinary "area measuring" or "radial" planimeters are used. The use of the "radial" planimeter for integrating "head" charts is also described.—M. B. R.

Line Coordinate Charts for Representing Chemical Engineering Data. Edw. A. Ravenscroft. Industrial & Engineering Chemistry, Dec. 1929, pages 1203-1210.

The purpose of this paper is to show how line coordinates may profitably be employed by the chemical engineer. The principle is explained, and the relative merits of charts constructed in line coordinates and in Artesian coordinates are discussed. Five charts are given, together with their method of construction and use. They relate to: vapor pressures, latent heats, boiling points of caustic solutions, hexane-octane liquid-vapor equilibria and humidity.—M. E. H.

Vapor Pressure Chart for Lower Aliphatic Hydrocarbons. R. L. Copson & Per K. Frölich. Industrial & Engineering Chemistry, Nov. 1929, pages 1116-1117.

Bibliography of 30 references. The chart has been prepared to represent accurately the vapor pressures of the lower hydrocarbons: methane, ethane, propane, the butanes and pentanes, and ethylene. This becomes a useful tool in solubility determinations and purification of these hydrocarbons and in their analysis by low temperature fractionations.—M. E. H.

Slide Rule for the Determination of the Stresses at the Top of Poles for Overhead Lines (Regle a calcul pour la determination des efforts en tete des supports de lignes aeriennes.) Charles Heckel. Revue General de l'Electricite, Oct. 5, 1929, pages 540-542.

Describes rule and explains its use.—M. S.

INSPECTION

Askania Tube Camera. (Askania Rohrkamera) Stahl und Eisen, Dec. 19, 1929, pages 1858-1859. Kinotechnik, Apr. 5, 1929, pages 179-182.

A special camera developed by the Askania firm is fully described. "The Rohr-Kamera," as it is called, is useful in photographing the interior of drill holes of unusual length for the purpose of detecting flaws in material or machine work. The camera comprises retorts for standard film, mechanism for giving the film a continuous motion, and a special optical system enclosed in a cylinder four meters in length. The lens cylinder is introduced into a drill hole and progessively fed along the axis. A small electric lamp attached to the forward end of the lens cylinder illuminates the object and a portion of its circumference is scanned by a right-prism of the lens system. By turning the lens system and repeating the operation different arcs of the circumference can be photographed. Since the film is arranged to move in perfect relation with the apparatus motion of the object no intermittent mechanism is necessary. Illustrations are given of the photographs obtained.

The Foster Introscope. Automobile Engineer, Oct. 1929, page 356.

The Foster Instrument Company, Letchworth, has produced an instrument for the examination of the interior surfaces of small bores and apertures. It consists of a light, mirror, prism, and a wide angle objective. These are so arranged that the surface appears as a direct view to the eye of the user. R. H. P.

LENGTH, AREA, VOLUME

An Instrument for the Measurement of Thickness of Compressible Solids. M. C. Marsh. Journal Scientific Instruments, Dec. 1929, pages 382-385.

A description is given of an instrument, combining sensitivity and robustness, for the measurement of the thickness of compressible solids over a very wide range of pressures.

A Method for Measuring the Internal Diameters of Transparent Tubes. F. H. Rolt, R. M. Wilmotte & J. S. McPetrie. Journal of Scientific Instruments, Dec. 1929, pages 379-381.

A method for measuring the internal diameters of transparent tubes employing 2 balls is described. Ellipticity and lack of parallelism may be detected and the ultimate limit of accuracy of measurement is determined by the accuracy to which the balls are spherical. A way of employing the method in the case of opaque tubes is suggested.

Handy Longitudinal Micrometer for Measuring Shrinkage of Perforated Films. Filmtechnik, Mar. 30, 1929, pages 133-134.

A micrometer rule, a device developed by the Agfa Company, is described. For use the film is secured by two lugs and laid on the face of the rule. The micrometer scale is read at the point corresponding to the extinction of certain black marks by the film between the perforations. The device is accurate to hundredths of a millimeter.—Abs. Bull. Kodak Res. Labs.

Accuracy of 0.00008" Needed to Make W. E. Condenser "Mike." Exhibitors Herald-World, Sept. 28, 1929, page 36.

Description of the mechanical operations required in assembling a sensitive microphone. The duralumin sheet used for a diaphragm is adjusted to a frequency vibration between 5000 and 5050 cycles a second. The back plate of the condenser must be within 0.00008 inch of a true plane.—Abs. Bull. Kodak Res. Labs.

Arrangement for Adjusting Snap-Gauges (Einrichtung zum Justieren von Rachenlehren). Koschawitz. Werksstattstechnik, Oct. 15, 1929, pages 597-598.

Description of a simple method to adjust snap-gauges.—G. N.

A New Parallel Plate Comparator. J. DuMond. Review of Scientific Instruments, Feb. 1930, pages 84-87.

Instrument is described.

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Taylor Instrument Co.

Electromechanic Instrument to Measure Fine Wires. (Elektromechanisches Messeraet fuer Feindrachte). M. Bartholdy. Kruppsche Monatshefte, Nov. 1929, pages 184-185.

The new instrument was developed because the present known methods to measure diameters of very fine wire include too many sources of errors. The instrument and its method of application, including discussions of the accuracy of measurement, are described. Diameters can be measured with an accuracy of .0001 mm.—G. N.

Comparator for Inside Micrometers. George C. Warren. American Machinist, Oct. 3, 1929, page 598.

A drill rod with movable collars and adjusting screws are used to compare the inside micrometers with a standard test bar.—R. H. P.

LIQUIDS

Fluid Flow in Pipes and Channels. S. J. Davies & C. M. White. Nature, Aug. 17, 1929, page 281.

A note on articles on the progress made in this branch of hydraulics.—Abs. Bull. Kodak Res. Labs.

A New Waterflow Indicator. G. D. Clark. Electric Journal, Dec. 1929, page 568.

A water-flow indicator with alarm contacts is described and illustrated. The indicator is calibrated in gallons per minute and the alarm contacts which are adjustable are positive in action and removed from the water circuit are circuit are suitable for direct or a. c. control. The indicator is designed so that full line pressure may be applied to it with the drain plug on I side open. Claimed advantages are listed.—W. H. B.

Propeller-Type Flow Meters. K. Trott. Engineering Progress, Oct. 1929, pages 279-280.

Describes the Ott Universal Flow Meter. This is a portable, propeller or screw-type meter. The rotation of the propeller, acting through a geared wheel periodically closes an electrical contact to a signal device. Claimed to work equally well in large or small streams with slow or rapid current.—R. H. P.

Water-Level Device Accurately Regulates Stream Flow Automatically and Within Predetermined Limits. Electrical West, Oct. 1, 1929, pages 194-195.

Engineers of the Pacific Gas and Electric Co. have developed an automatic sluice-gate control, which is installed at the company's Pit River No. 4, diversion dam. By means of floats, suitable relays, contacts, tapping motor etc., the gate motor is set into operation. A float will accommodate the 2 floats, 1 each for operating the open and the closed control contacts. The floats are mounted on a yoke so that they may be raised or lowered by means of a calibrated handwheel to suit the desired river flow.—M. S.

GASES, AIR, STEAM

Apparatus for the Analysis of Small Samples of Gas. H. R. Ambler. Analyst, Sept. 1929, pages 517-522.

A simple apparatus has been devised which will analyze samples of gas of 1 c.c. with an accuracy of 1%, and 15 c.c. with an accuracy of 0.1%. It is possible to carry out a determination on as little as 0.25 c.c. of gas at N. T. P. The gas, after removal of any constituent, is brought to constant volume, the results being calculated from the manometer readings. It is possible to analyze a gas of 6 constituents in 30 mins.—Abs. Bull. Kodak Res. Labs.

A Simple Control Stopcock for Gas Analysis Apparatus. Martin Shepherd. Bureau of Standards Journal of Research, Jan. 1930, pages 23-26.

This note describes a simple control stopcock for gas analysis apparatus. The control permits pressure balance to be obtained easily, quickly, and with high accuracy. Diffusion errors are eliminated without danger of emptying the manometer. The accidental surge of pipette reagents into the train is prevented. Difficult combustons of heavy hydrocarbons may be made without the deposition of carbon. The technique of operaton and actual means of construction of the stopcock are described.

Flow Meters in a Sugar Refinery. Facts about Sugar, Jan. 11, 1930, pages 44.

A. C. Nielson Company shows large steam saving with Brown Flow Meters.

The Measurement of Air Quantities and Energy Losses in Mine Entries. Part IV. Clyde M. Smith. Bulletin No. 199, Engineering Experiment Station University of Illinois.

The work reported in this bulletin supplements the results of the previous investigations, reported in Bulletins Nos. 158, 170 and 184, in supplying information as to the losses in closely timbered entries, the energy saved by smoothing up such an entry, and the losses caused by 3-piece timber sets and center posts placed on various centers.

ELECTRICITY

Method for the Determination of the Absolute Value of the Ohm. M. Picard. Comptes rendus, July 17, 1929, pages 125-126.

A circuit is shown which makes it possible to compare a resistance and the coefficient of induction as a function of frequency. Inductance is determined by geometrical measure.—Abs. Bull. Kodak Res. Labs.

Detachable Watt-Hour Meters. Electrical World, Dec. 7, 1929, page 1157.

A detachable meter for indoor or outdoor service and designed by Westinghouse Electric & Manufacturing Co. consists of the standard temperature compensated OB watt-hour meter housed in a weatherproof case. Advantages claimed for it are: plug terminals, easily removable suitability for mounting in any location, reduction in labor, reading and testing costs, it is tamper proof, and has an adjustable terminal block which permits mounting the meter with conduit entrance at top, bottom, right or left.—W. H. B.

Synchronous Reactance Measured with Machine in Use. L. Clifton Snively. Electrical World, Dec. 28, 1929, page 1285.

Reactance is measured with the machine in use by having the reactance drop in one phase of the alternator balanced by another in which the line current is flowing in the opposite direction. This is effected by connecting through a low-reading ammeter and a low-reading voltmeter to the secondary of a current transformer in the line. Actual regulation of an alternator by loading it at unity power factor and then throwing its load off was 13.63%; the regulation is obtained by calculation and using the synchronous reactance determined by the above method was 13.15%, while other methods gave 20.8 and 6.67%. The connections are illustrated.—W. H. B.

Verifying Connections in Low-Tension Metering. A. F. Newman. Electrical World, Dec. 7, 1929, page 1119.

A simple connection check for low-voltage meter installation for 3-wire circuit of 1-, 2-, or 3-phase requires only a set of test leads with "Universal" test clips and a 100-watt lamp. The connection check is illustrated.—W. H. B.

BUYER'S GUIDE

Thermometer
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.

Thermostat
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Taylor Instrument Companies
Westinghouse Elec. & Mfg. Co.

Thickness
Esterline-Angus Company
H. Z. Schniewind

Time
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Stromberg Electric Co.
Tagliabue Mfg. Co., C. J.

Vacuum
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.

Unit Heater

Valve—Motor Operated
American Radiator Company
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Taylor Instrument Companies

Water Level
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Tagliabue Mfg. Co., C. J.

COORINATOGRAPHS

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Brown Instrument Co.
H. Z. Schniewind

Stroke
Bristol Company
Esterline-Angus Company

COUPLING TRANSFORMERS
General Radio Company

CURRENT RECORDERS
Esterline-Angus Company
Leeds & Northrup Co.

CURRENT REGULATORS
Westinghouse Elec. & Mfg. Co.

CYCLE COUNTERS
General Radio Co.

CYLINDERS-GRADUATED
Tagliabue Mfg. Co., C. J.

DECELEROMETER

DEFORMETER (Beggs)
Southwark Fdy. & Mach. Co.

DEMAND METERS

Gas
American Meter Co.

Electric
Westinghouse Elec. & Mfg. Co.

DENSITOMETERS
Akatos, Inc.

DENSOMETERS
H. Z. Schniewind

DIVIDING HEAD

Optical
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.

DIVIDING MACHINES
Gaertner Scientific Corp.

DRAFT GAGES—see Gages

DYNAMIC BALANCING EQUIPMENT
Electrocon Corporation

EARTH CURRENT METERS
Rawson Elec. Inst. Co.

ELECTRIC TELEMETER
Southwark Fdry. & Mach. Co.

ELECTRIC WAVE FILTER SECTIONS
General Radio Company

EMPLOYEES' "IN AND OUT" TIME RECORDERS
Stromberg Electric Co.

ENGINE INDICATORS
Commercial Engg. Labs.

EXTENSOMETER
H. Z. Schniewind
Southwark Fdry. Mach. Co.

FATIGUE TESTERS
H. Z. Schniewind

FAULT FINDERS
General Radio Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

FLASH & BURNING POINT TESTERS
Akatos, Inc.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Co.

FLOW METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.

FLUXMETERS
Leeds & Northrup Co.
Rawson Electrical Instr. Co.

FOLDING TESTER
H. Z. Schniewind

FREQUENCY METERS

Indicating
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Weston Elec. Inst. Corp.

Controlling
Leeds & Northrup Co.

Recording
Bristol Company
Esterline-Angus Company
Leeds & Northrup Co.

Standards
General Radio Co.

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Burgess-Parr Co.

FUEL FLOW INDICATOR
Commercial Engg. Labs.

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Brown Instrument Co.
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General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

GAS ANALYTICAL METERS

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American Meter Co.
Tagliabue Mfg. Co., C. J.

Electrical
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Charles Engelhard, Inc.
Leeds & Northrup Co.

GAS LEAK INDICATORS
Taylor Instrument Companies

GAS-METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.

GASOMETERS
American Meter Co.

GAGE RODS
Tagliabue Mfg. Co., C. J.

GAGES

Absolute Pressure
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Foxboro Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

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B. C. Ames Co.
Federal Products Corp.

Comparator
B. C. Ames Co.
Federal Products Corp.

Cylinder
B. C. Ames Co.
Federal Products Corp.

Depth
B. C. Ames Co.
Federal Products Corp.

Dial
B. C. Ames Co.
Federal Products Corp.
H. Z. Schniewind

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Brown Instrument Co.
Foxboro Co.
Tagliabue Mfg. Co., C. J.

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Brown Instrument Co.
Foxboro Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

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Industrial App. & Inst. Co.

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Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

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Foxboro Co.

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Federal Products Corp.

Pocket
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Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

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Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.

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Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

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Industrial App. & Inst. Co.

Rain
Taylor Instrument Companies

Recording

Distance
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Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.

Strain
Southwark Fdry. & Mach. Co.

Thickness
B. C. Ames Co.
Esterline-Angus Company
H. Z. Schniewind

Testers Check Standards. O. P. Stickney. Electrical World, Nov. 30, 1929, pages 1072.

The meter dept. of the Nebraska Power Co. has a board for making daily checks of rotating standards when a meter tester returns after his day's work. The meter has a special cover that blocks off the register and half of the normal disk exposure. This gives a sharp fixed edge against which the movement of the mark on the disk is observed. The tester takes one light and one heavy load run on his standard. The check takes but a minute or so.—W. H. B.

A New Cathode Oscillograph and Its Application to the Automatic Recording of Lightning and Switching Surges (Un nouvel oscillographe cathodique at son application a l'enregistrement automatique des eclairs et des suttensions de commutations). L'Industrie Electrique, Oct. 25, 1929, pages 461-463.

From an article by R. H. George in Jl. A. I. E. E., July 1929. This oscillograph employs a new electrostatic method of focusing the beam. It will operate at any beam potential from 500 to 20,000 volts and at very low gas pressures. High photographic sensitivity at medium voltages is attained by the use of a high-intensity beam. For recording lightning surges, a portable form is used, together with circuits by means of which the lightning surge automatically starts the beam in from $\frac{1}{2}$ to $\frac{1}{4}$ microseconds after the surge voltage begins to rise from zero.—M. S.

The "Trivector;" a New Kilovolt-Ampere-Hour Meter Usable from $\cos\phi=1$ to $\cos\phi=0$ and its Importance for the Operation of Electrical Systems (Le "Trivector;" nouveau compteur d'energie apparente utilisable de $\cos\phi=1$ a $\cos\phi=0$ et son importance pour l'exploitation des reseaux electriques). W. Janicki. L'Industrie Electrique, Oct. 10, 1929, pages 447-451.

Gives a brief account of the various methods of establishing rates in use by different large electric power companies, and describes a new kilovolt-ampere-hour meter applicable to widely varying power factors.—M. S.

Sensitivity of a Galvanometer as a Function of Its Resistance. H. B. Brooks. Bureau of Standards Journal of Research, Feb. 1930, pages 247-312.

Maxwell derived a theorem which states that for the maximum deflection of a galvanometer connected to a given external circuit containing a given electromotive force the ratio of galvanometer resistance to external resistance should be equal to the ratio of the diameter of the wire in the galvanometer coil (before insulation) to the diameter including the insulation. Ayrton and Perry later stated that the galvanometer resistance should be equal to the external resistance. The widely quoted statement differs from Maxwell's because Maxwell assumed an unchanging thickness of insulation, Ayrton and Perry a thickness varying directly as the diameter of the bare wire.

The present paper demonstrates that while both statements are correct for their respective assumptions, the sensitivity function in each case is very flat in the vicinity of the Maximum, that aside from considerations of damping the user has a wide range of choice of galvanometer resistance with relatively small loss of sensitivity, and can in fact sometimes obtain much better sensitivity with moving-coil galvanometers (when critical damping is considered) by departing from the theoretical optimum value of resistance. A general curve of the sensitivity function for the Ayrton-Perry assumption is given with a similar curve for a particular case for the Maxwell assumption. The performance of four lines of commercial galvanometers is shown by plotted points.

The constructional limitations and those related to damping which must be considered in applying the conclusions of the paper are outlined, and the practical advantages of the facts brought out to both maker and user, are briefly summarized.

Electricity Meter Jewels. "A Station Engineer." Electrical Rev., Oct. 11, 1929, pages 545-546.

Discusses some points in regard to bearing materials, which require further investigation among these are the suitability of diamonds; the use of steel ball bearings; testing by running meters millions of revolutions; and the coefficient of friction between the 2 surfaces in contact.—M. S.

Novel Electricity Meter. Electrical Review, Nov. 8, 1929, pages 830-831.

Describes the constructional details of the "Rex" fixed-charge automatic collector and prepayment meter.—M. S.

A Bridge Ohmmeter. Electrical Review, Sept. 13, 1929, page 452.

Describes a combined ohmmeter and Wheatstone bridge recently introduced by the Record Electrical Co. for the purpose of measuring low resistances.—M. S.

Compact Testing Set. Electrical Review, Oct. 25, 1929, page 707.

Describes the "Ferranti" multi-range d.c. testing set.—M. S.

Measurements of Very High Tensions by Means of a Spark-Gap With Spherical Electrodes in Air (Mesures de tres hautes tensions a l'aide d'un eclateur a electrodes spheriques dans l'air). A. Segall. Revue General de l'Electricite, Oct. 19, 1929, pages 617-619.

Abstract of article by C. Stoerk and M. Holzer in Zeits. Fuer Technische Physik, Aug. 1929, page 317. Describes apparatus employed and the arrangement, and the precautions taken, and gives results obtained.—M. S.

Method of Metering the Energy Used by Portable Motors (Procede de comptage de l'energie absorbee par des moteurs transportables). Andre M. Mieg. Revue generale de l'Electricite, Nov. 9, 1929, pages 758-760.

Proposes a method, applicable to 3 phase networks, which consists in providing for each motor 2 balanced three-phase meters with a single wattmeter element.—M. S.

Shielding in High-Frequency Measurements (Le blindage dans les mesures a'haute frequence). John G. Ferguson. L'Industrie Electrique, Nov. 25, 1929, pages 521-524.

Condensed translation from Jl. A. I. E. E. July 1929, pages 517-521. Outlines purpose and usefulness of shielding in high-frequency measurement. Develops general principles of electrostatic shielding as applied to simple impedances and to networks of impedances, particularly to bridge networks. Describes practical applications of these principles.—M. S.

Transmission Line Surges. H. Norinder. Electrical Review, Dec. 13, 1929, pages 1072-1073.

Extracts from a lecture delivered before the Institution of Electrical Engineers. Includes consideration of klydonographs and cathode-ray oscillographs, used to investigate lightning disturbances.—M. S.

High-Voltage Indicator. Electrical Review Dec. 13, 1929, page 1066.

Brief description of "Martindale" indicator, produced by Martindale Electric Co. Consists of a highly sensitive neon discharge tube, equipped with special electrodes and assembled in a glass housing, capped with brass ferrules. Tube draws its necessary power by condenser action.—M. S.

Super-Voltage Measurement. Electrical Review, Nov. 29, 1929, pages 967-968.

British Thomson-Houston Co., Ltd., has introduced a method of measuring high voltage from the low-voltage side of a. c. systems, using "compensating" circuits to reproduce accurately the primary-circuit conditions.—M. S.

BUYER'S GUIDE

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Foxboro Co.
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Bristol Company
Brown Instrument Co.
Foxboro Co.
Wind
Brown Instrument Co.
Taylor Instrument Companies

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American Meter Co.
Pressure
Brown Instrument Co.
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Tagliabue Mfg. Co., C. J.
Pump
Tagliabue Mfg. Co., C. J.

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GREASE TESTING APPARATUS
Tagliabue Mfg. Co., C. J.

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Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electric Inst. Corp.

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Industrial App. & Inst. Co.
H. Z. Schniewind
Wilson-Maeulen Company, Inc.

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HELIOSTATS
Gaertner Scientific Corp.

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Argeo Laboratories, Inc.

HIGH VOLTAGE
Indicators
Argeo Laboratories, Inc.
Measuring Devices
Westinghouse Elec. & Mfg. Co.
Testing Devices
Westinghouse Elec. & Mfg. Co.

HUMIDITY CONTROLLERS
Charles Engelhard, Inc.
Foxboro Co.

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Wet & Dry Bulb Thermometers
Bristol Company
Brown Instrument Co.
Foxboro Co.
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Taylor Instrument Companies

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Indicating
Leeds & Northrup Co.
Rubicon Company
Controlling, Recording
Leeds & Northrup Co.

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Taylor Instrument Companies

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H. Z. Schniewind
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Taylor Instrument Companies

IMPACT HARDNESS TESTER
H. Z. Schniewind

IMPACT TESTING MACHINES
Akatos, Inc.
H. Z. Schniewind
Alternating

INDICATORS—See Gauges

INDUCTANCES
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Rubicon Company

INSTRUMENT BOOKS
Instruments Publishing Co.

INSTRUMENT CALIBRATION AND REPAIRS
Jewell Electrical Instrument Co.
Rubicon Company

INSTRUMENT TRANSFORMERS
Jewll Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

INSULATION TESTING EQUIPMENT
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Rubicon Company
Westinghouse Elec. & Mfg. Co.

INTEGRAPHS & INTEGRATORS
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Stromberg Electric Co.

KEYS AND SWITCHES
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

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Foxboro Co.

KILOVOLT AMPRERE METERS
Esterline-Angus Company

KLYDONOGRAPHS
Westinghouse Elec. & Mfg. Co.

LACTOMETERS
Tagliabue Mfg. Co., C. J.

LENGTH MEASURING MACHINES
Gaertner Scientific Corp.
H. Z. Schniewind

LEVELS
Centering
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Engineer's, Wye, Precision
Prism
Taylor Instrument Companies

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American Instrument Company

LOCOMOTIVE INDICATORS

LUSTER METERS
Akatos, Inc.

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Rubicon Company

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American-Paulin System, Inc.
Brown Instrument Co.
Foxboro Co.

MASTER CLOCKS
Gaertner Scientific Corp.
Stromberg Electric Co.

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Instrument Publishing Co.

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Leeds & Northrup Co.
Rubicon Company
Herman H. Sticht and Company

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Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

MELTING POINT APPARATUS
Tagliabue Mfg. Co., C. J.

METER PRCVERS, Gas
American Meter Co.

METER TESTERS, Gas
American Meter Co.

MICROMETERS
Gaertner Scientific Corp.
H. Z. Schniewind

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Rawson Electrical Instrument Co.
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Wilson-Maeulen Company, Inc.

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Gaertner Scientific Corp.
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Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Spencer Lens Co.
Petrographical
Akatos, Inc.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Spencer Lens Co.
Toolmakers'
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Industrial App. & Inst. Co.
Spencer Lens Co.

MICROTOMES
Bausch & Lomb Optical Co.
Spencer Lens Co.

MILLIAMMETERS
Charles Engelhard, Inc.
General Radio Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MILLIVOLTMETERS
Bristol Company
Charles Engelhard, Inc.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Taylor Instrument Companies
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MOTION RECORDERS
Mechanical
Bristol Company

MULTIMETERS
Rawson Electrical Instrument Co.

MULTIPLIERS
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Weston Electrical Inst. Corp.

NEON FILLED TUBES
Argeo Laboratories, Inc.

NEPHELOMETERS
Akatos, Inc.

OHM METERS
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co.
Rubicon Company
Herman H. Sticht and Company
Weston Electrical Inst. Corp.

OIL TESTING APPARATUS
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

OIL TESTING EQUIPMENT

OPERATION RECORDERS
Electrical
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

Fundamentals of Correct Metering, III. E. C. Goodale. Electrical West, Nov. 1, 1929, pages 243; Dec. 1, 1929, pages 297-299.

Discusses the application of Blondel's theorem to the metering of a 5-wire circuit with a meter connected load. Part IV is devoted to the application of Blondel's star-connected load. M. S.

Measuring Instruments for Watt and Reactive Components (Messgeraete fuer Wirk- und Blindleistung). Otto Zwierina. Elektrotechnische Zeitschrift, Dec. 19, 1929, pages 1844-1848.

The construction of a precision instrument for measuring the watt component and the reactive component of energy consumption is described in detail. To effect such measurement with the same instrument a switch is provided to arrange a proper phase relation of the voltages as the voltage of the watt component is 90° different from the voltage of the reactive component. The influence of temperature and frequency is discussed and the application in single-phase and multiphase installations described. Two examples illustrate the use of the instruments.—Ha.

Substitute Connection for the Simultaneous Calibration of Both Measuring Systems in a Three-Phase Meter (Ersatzschaltung fuer die gleichzeitige Eichung vom Drehstromzahlern mit zwei Messwerken). Wihl. Beetz. Elecktrotechnische Zeitschrift, Dec. 19, 1929, pages 1839-1837.

The author has developed a connection for the calibration of 3-wire 3-phase meters which gives exactly the same calibration values as the Aron-connection provided that the inner phase relation (power factor) is properly adjusted in both measuring systems and that the latter exert exactly the same torque. For this only single-phase current is required. It is preferable to carry out the calibration with a standard meter instead of a wattmeter as this permits a more accurate adjustment of the torques of the 2 systems in the meter to be calibrated.

Notes on the Design of 4-Terminal Resistance Standards for Alternating Currents. Frances B. Silsbee. Bureau of Standards Journal of Research, Jan. 1930, pages 73-107.

The design of a resistance standard for use with alternating current involves not only the consideration of the value, definiteness, and permanence of the resistance and the adequate cooling of the metal parts, which are encountered in direct-current standards as well, but also the consideration of the inductance and of the possible change in the resistance of the standard with the frequency of the current flowing in it. These notes give the theoretical basis for the computation of the inductance of resistance standards which consist of a system of straight conductors long in comparison to their diameters. Most standards used in the measurement of a-large currents are of this type. Formulas are given for the skin effect in various combinations of flat strips and coaxial tubes. Methods of attaching and locating the potential leads so as to minimize the possibility of error from stray magnetic fields and yet permit of convenient adjustment of the resistance are discussed. As examples of the principles here set forth, detailed descriptions are given of two groups of resistance standards which have been constructed at the Bureau of Standards for testing current transformers. These standards range in resistance from 0.05 to 0.0002 ohm and in current capacity from 10 to 2,500 amperes.

Method and Apparatus Used in Testing Piezo Oscillators for Broadcasting Stations. E. L. Hall. Bureau of Standards Journal of Research, Jan. 1930, pages 115-130.

Piezo oscillators are the most suitable frequency standards thus far devised for use in radio broadcasting stations. A piezo oscillator may be used either to check the frequency of the station or to control its frequency. Most of the piezo oscillators tested by the bureau are for use in checking the frequency of the station. Piezo oscillators are capable of high precision in the measurement of their frequency if a beat note is produced by adjusting another generator to a similar frequency. This principle is employed in the methods and apparatus described in the paper. After preliminary tests to determine the suitability of the quartz plate and its fundamental frequency, the piezo oscillator is kept in a temperature-controlled room for not less than two days. During which frequency measurements are made. The method consists in measuring the frequency of the piezo oscillator under test in terms of a 200 kc temperature-controlled piezo oscillator. This is accomplished by adjusting a radio-frequency generator to the frequency which the piezo oscillator under test should have. This adjustment is made by using harmonics from a 10 kc generator which is kept accurately set in terms of the 200 kc standards by observing a special form of beat indicator. The frequency difference between the test piezo oscillator and the generator set in terms of the standard is measured by comparison with an audio-frequency generator. A frequency meter of special design is used to check the frequency difference and determine the sign of the correction to be applied. The method described is also useful in the calibration of frequency meters and the measurement of station frequencies.

TEMPERATURE AND MOISTURE

An Apparatus for Tracing the Change in Moisture Content of Small Quantities of Powder. J. Lampett. Journal Scientific Instruments, Dec. 1929, pages 369-373.

This paper describes in detail a method of tracing the change in weight of small quantities of powder due to absorption or loss of moisture in an atmosphere of known humidity. The principle depends upon observing by means of a travelling microscope the rise or fall of an arm of a delicate torsion balance.

New Tray Thermometer. M. Zeppermayr. Kinotechnik, May 5, 1929, pages 234-235.

A new design of thermometer is described which differs from the ordinary type in that the mercury bulb is contained in an elbow. In use the elbow is hung over the edge of a tray, and the open end being weighted always rests on the table. The temperature range is 8° to 50°C. —Abs. Bell Kodak Res. Labs.

An Apparatus to Measure Color Temperature of Incandescent Lamp Filaments. C. H. Sharp. Journal Optical Society, Feb. 1930, pages 62-70.

The paper describes a instrument whereby color matching can be done with great facility.

Moisture Content of Carbon Blacks. W. B. Plummer. Rubber Age, Feb. 10, 1930, pages 487-488. Reprint from Analytical Edition, Industrial & Engineering Chemistry, Jan. 15, 1930.

The Transition Temperature of Carbon Tetrachloride as a Fixed Point in Thermometry. Evald Eskau & Harry F. Meir. Journal American Chemical Society, Dec. 1929, pages 3517-3519.

The transition point has been redetermined on a very pure sample in a special apparatus using a thermocouple whose calibration has been very carefully checked. The transition takes place at -47.55 ±0.12°, about one degree higher than reported by McCullough and Phipps, Jl. Amer. Chem. Soc., 50,2213 (1928). The transition point is apparently not suitable as a fixed point for thermometry according to the authors.—M. E. H.

BUYER'S GUIDE

ORIFICE METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.
ORSAT APPARATUS
OSCILLOGRAPHS
General Radio Co.
Westinghouse Elec. & Mfg. Co.
OXYGEN RECORDERS
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
PANTOGRAPHS
Gaertner Scientific Corp.
PERFORMANCE METER
PERMEAMETERS
Leeds & Northrup Co.
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H. Z. Schniewind
Spencer Lens Co.
PERISCOPES
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
PHASE INDICATOR
Westinghouse Elec. & Mfg. Co.
PHASE SEQUENCE INDICATOR
Herman H. Sticht Co.
PHOTO-ELECTRIC CELLS
Argeo Laboratories, Inc.
PHOTOMETERS
Akatos, Inc.
American Meter Co.
Gaertner Scientific Corp.
Bausch & Lomb Optical Co.
Industrial App. & Inst. Co.
Leeds & Northrup Co.
PHYSICAL TESTING MACHINES
Industrial App. & Inst. Co.
H. Z. Schniewind
Southwark Fdry. & Mach. Co.
PITOT TUBE METER
Brown Instrument Co.
Foxboro Co.
PLANIMETERS
Automatic Flow Record
Brown Instrument Co.
Linear
Brown Instrument Co.
Radial
American Meter Co.
Bristol Company
Bristal Company
Foxboro Co.
POLARISCOPES
Akatos, Inc.
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ELECTRIC REFRIGERATOR MEASUREMENTS.

WILLIAM LEE HOLLADAY, INSTRUMENTS, Vol. 3, No. 3, March 1930, pages 153-156, 3 figs.

The articles briefly considers the measurements made on household electric refrigerators.

AN EARLY USE OF MAGNETISM FOR MECHANICAL TESTING.

DR. S. R. WILLIAMS, INSTRUMENTS, Vol.3,No.3,March 1930,pages 157-158, 4 figs.

The author describes an early application of magnetism for mechanical testing. This was done by Sturgeon in 1867, who proposed testing "the iron of guns by magnetic power."

ENGINEERS HANDBOOK OF INDUSTRIAL INSTRUMENTS:

M. F. BÉHAR, INSTRUMENTS, Vol. 3, No. 3, March 1930, pages 159-182, 23 figs.

This is the third installment of the Handbook and is devoted to the measurement of temperature by means of thermometers.

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MEASUREMENTS—INDUSTRIAL AND SCIENTIFIC.

DR. WALTER BLOCK, INSTRUMENTS, Vol. 3, No. 2, March 1930, pages 183-196.

This installment of Dr. Block's book is devoted to general remarks on measurements and their manipulation. It considers: accuracy, errors in measurement and reliability of measurements.

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